# Academic Revolution and Regional Innovation:

# The Case of Computer Science at Stanford

# 1957-1970

Danny Crichton

May 17, 2011

## Abstract

There remains little consensus in regional studies on the origins of Silicon Valley or other innovation hubs. Different approaches, reflecting the interdisciplinary nature of the field, have examined the issue from institutional, cultural, and network analysis perspectives. At the same time, historians of science are beginning to construct a more detailed narrative of the development of computer science in the United States, particularly in the divide between academic theory and industrial practice.

This study embraces these two literatures by analyzing the case of Computer Science at Stanford University and its connection to the rise of Silicon Valley. It finds that the dispute between computer science faculty and other basic scientists led to an academic culture in the Computer Science department that encouraged research on theory, while at the same time, limited funding from the university developed a pragmatic culture that encouraged engagement with industry and created valuable knowledge networks that helped to spark the development of Silicon Valley. This study provides the first archival-based research analysis of computer science at Stanford, and will be useful to scholars in history of computing, history of higher education, regional studies as well as scholars in science, technology and society.

# Contents

# Acknowledgements

Since the formulation of this study eighteen months ago, I have had the opportunity to interact with an incredible number of people who have greatly assisted me with the development of this project.

I would like to thank Stanford University's Undergraduate Advising and Research for providing a Major Grant to conduct research over the summer of 2010. The summer experience not only provided the time away from studies needed to conduct high-quality research, but provided me the opportunity to concentrate on my long-term goals. My application and eventual acceptance as a Fulbright Scholar was largely contingent on the time provided to put together a quality application.

I would also like to thank the staff of the Stanford University Archives, who taught me the essentials of using an historical archive and provided copious sources upon which this study is drawn. Their efficient service was greatly appreciated.

Presenting research is an important element of understanding one's ideas, and

I would like to thank Feross Aboukhadijeh and Jake Becker for the opportunity to present my research to the Stanford chapter of the Association for Computing Machinery.

This thesis was written in LaTeX, a document preparation system built on top of TeX. I would like to thank Donald Knuth, a professor of Computer Science at Stanford University, for developing this system and for his vast intellectual contributions to the field. While he makes a cursory appearance in this study due to its scope, his contributions to the development of Stanford's program are extraordinary and deserve greater historical attention.

Many professors had an impact on this project. I would like to thank Russ Altman for encouraging me to pursue a career at the interface of science and policy. I would particularly like to thank Russell Hancock and Frank Benest and the members of a seminar at Stanford called "Regional Politics and Decision-Making in Silicon Valley" which inspired me to consider the connections between the history of science and regional studies. Finally, I would like to thank Robert McGinn, who inspired my interest in science, technology and society and taught me much of the theoretical material that underpins this thesis.

Rebecca Slayton's hard work and dedication throughout the process of this project has been instrumental in the final quality of this study. Her assistance in connecting my original proposal to STS along with her incredible knowledge (and bookshelves!) on the history of computing have been invaluable. Furthermore, her dedication to reading every draft has improved the quality of this study dramatically. Finally, her organization of both the STS honors seminar and STS faculty research seminar provided important forums for communicating my work and connecting to interesting scholars including David Kaiser and Nathan Ensmenger.

I would like to thank the members of the STS honors seminar for their feedback on multiple drafts and for great moments of commiseration as deadlines approached.

I have a particular debt of gratitude for Barton J. Bernstein, who has been a constant mentor and adviser since my freshman year and who has spent many dozens of hours advising me on this study and my academic career. His seminar, approaching its fiftieth anniversary on the atomic bomb and politics, provided me with an ability to think critically about research like no other class at Stanford. Bernstein has assisted me with this study every step of the way, and his rigorous comments and eye for detail in my sourcing greatly increased the quality of the final product. He is the best that academia has to offer.

As an historian, I also feel responsible for thanking those who brought me to Stanford in the first place. In particular, I would like to thank Colleen Nuese-Marine of Eden Prairie High School, who developed my writing abilities for four years as school newspaper adviser. Her constant dedication to improving my style is present throughout this work. I would also like to thank my preschool teachers, Jackie Jamieson and Roseanne Wall, who provided me an infinite supply of paper and helped to ignite my writing career.

Finally and most importantly, no project of this magnitude can succeed without the love and affection of friends and family. Philip Bui and Sunny Vanderboll have been constant friends throughout my time here at Stanford, and their ability to listen to my research at odd hours when inspiration struck has been marvelous. Vanderboll's interests in urban planning and regional development show hints throughout this essay, and my intellectual and personal development was mutually shaped by Bui for whom I am eternally grateful.

It is my parents though to whom this thesis owes the deepest debt. Jan and Mark have been steadfast in their support of my education for my entire life, and their sacrifice to support my time at Stanford can never be fully acknowledged. The journey of a thousand miles begins with a single step, and they have been supportive of me every single step of the way on this journey.

All errors in this study are, of course, my sole responsibility.

# Chapter 1

# Introduction

## 1.1 Preface

On April 16th, 2010, Stanford University hosted Angela Merkel, Chancellor of Germany and leader of the fourth largest economy in the world. While her only public speech focused on Afghanistan and the global financial crisis, the primary goal of her visit was to observe the newly built Volkswagen Automotive Innovation Lab.[1] The lab is designed for interdisciplinary teams of Stanford faculty members and their global industrial partners to conduct joint research projects. The center is the embodiment of the kind of university-industry partnerships desired by Germany and countries across the world.

Germany's leader was not the only head of state to visit the region that spring. Just a few weeks later, Stanford would welcome Russian President Dmitri Medvedev, who was touring Silicon Valley — perhaps the best example of the possibilities of academic-government-industrial networks. The president's goal is to duplicate the success of the region in the city of Skolkovo outside Moscow.[2] During his visit, "Medvedev said he wanted to create an atmosphere that mirrors the relationship between Stanford and Silicon Valley, and acknowledged a brain drain that's costing his country bright young scientists and business leaders."[3]

[1] Tyler Brown, "Merkel addresses Afghanistan, climate change," The Stanford Daily, 16 Apr. 2010.

[2] Andrew Clark, "Dmitry Medvedev picks Silicon Valley's brains," The Guardian, 23 Jun. 2010.

[3] Adam Gorlick, " 'I wanted to see with my own eyes the origin of success,' Russian president tells Stanford audience," Stanford News Report, 23 Jun. 2010.

Medvedev's mission is hardly unique. Countries across the world are developing plans and investing heavy resources in the pursuit of creating the next Silicon Valley — a regional innovation hub with a strong network of research universities, entrepreneurial companies and professional service firms. South Korea has embarked on a plan to enhance its human capital, forming the Ministry of Knowledge Economy in 2008 and developing plans for a massive new international campus outside Seoul.[4] The well-endowed establishment in 2009 of King Abdullah University of Science and Technology in Saudi Arabia is spearheading the creation of a new center of innovative science and technology in the Middle East.[5]

## 1.2 Understanding the Role of Universities in Regional Innovation

This incredible worldwide interest in regional innovation hubs has led to significant interest in their historical development. As will be seen later in this chapter, scholars have developed several methodologies to analyze the origins of them, and this study connects with three of these approaches. Historical institutional approaches take as their subject an organization within a region's research system

[4] According to the promotional pamphlet for the complex, the goal is to become an Asian education and research hub through the creation of a new campus for the prestigious Yonsei University and a nearby R&D park that will connect the university to industry.

[5] Its initial endowment of $10 billion is larger than that of MIT. Charles Q. Choi, "Arabian Brainpower," Scientific American, 17 Jan. 2008

and analyze the economic, social, political and cultural factors that shape it and how it shapes other entities in the system. Two other approaches look at regions as a whole from the bottom-up and top-down. Historical cultural approaches develop theories of innovation from the bottom-up by focusing on groups of people with sociologically similar characteristics — for instance, members of the countercultural movement in San Francisco. Finally, network analysis approaches use "relationships" such as patents or publications to investigate the development of patterns of innovation from the top-down.

All of these methodologies place universities as a core element in the rise of regional innovation hubs, and particularly in the development of computing and Silicon Valley. Despite the substantial research conducted on the latter two areas however, there has been comparatively little work on the institutional factors that assisted and hindered the development of academic computer science programs. Such an historical question may not seem pertinent at a time when universities place innovation equal to teaching and research as institutional priorities, and governments are increasingly demanding that universities assist with economic growth.[6]

As this study will show, universities are divergent in their abilities to engage with regional innovation, and analyzing these factors can better explain the rise of

[6]The change in attitude, particularly since the passage of the Bayh-Dole Act in 1980, has led to significant dissent within the academic community. For one critical albeit uneven account, see Daniel S. Greenberg, Science for Sale: The Perils, Rewards and Delusions of Campus Capitalism, University of Chicago Press, 2007.

Silicon Valley as well as the wide variance of success of different regional innovation hubs and their constituent universities. Furthermore, such research provides a new perspective on models of science and technology development, which form some of the core theories in research policymaking.

This study analyzes the rise of the Computer Science department at Stanford University, starting from 1957 with the hiring of mathematician George Forsythe to around 1970. It takes as its primary lens an historical institutional approach, focusing on the development of an academic department and its related discipline within the milieu of a research university. However, this study also uses historical cultural and network analysis lenses to analyze specific institutional factors that favored Stanford's engagement with the development of computing in Silicon Valley. This research is based on in-depth archival work with eight different collections, and it provides the first extensive history of the department.

This study has several potential audiences. It is most immediately directed toward scholars of regional innovation hubs, a diverse group that includes economists, political scientists, historians and anthropologists. In addition, this study provides the first archival-based analysis of the rise of computer science at Stanford, a top department that has shaped the field since its inception. This perspective will be of interest to the growing community of scholars investigating the history of computation and information technology. This study also develops new perspectives on how university administrators manage the development of new disciplines, which will will be of interest to scholars of higher education. Finally, this study provides an empirical application of some of the core theories of science, technology and society, particularly those theories related to the social construction of science and technology.

This chapter begins with a brief history of theoretical models of science and technology. Next, it will develop a fuller understanding of the three approaches to understanding regional innovation outlined above, with particular attention on the historical institutional approach. An important component to this study is the rise of computer science as a discipline within the academy, and a discussion of recent work analyzing this history will follow. Finally, this chapter will end with a brief history of Stanford and the growing literature of research analyzing its research model in the Cold War context.

## 1.3 Theoretical Models of Science and Technology

Theoretical models of science and technology related to computation and regional innovation hubs can be placed into three overlapping but intellectually coherent groups. Each group emphasizes different directions of influence between and among the three major components — science, technology, and society. The first group tends to treat technology and resulting social change as a product of science. The second group of models emphasizes the opposite kind of influence, the ways that social factors influence both scientific knowledge and technical innovation. The third and final group are contextual, in that they emphasize all three bidirections of influence most broadly — between science, technology, and society.

### 1.3.1 Technology as "Applied Science"

Vannevar Bush's linear model of science and technology research remains the most influential theory for understanding the creation of new knowledge. Bush had a long and storied career, with important connections to computing. During World War II, he led the Office of Scientific Research and Development, where he pioneered the basic research funding system largely intact today.[7]

In mid-1945, Bush wrote a policy paper on the state of scientific research and development.[8] The essay makes a vigorous defense for the funding of scientific research by the U.S. federal government, both to fight disease and to protect the nation's security. However, it is the development of Bush's conceptual understanding of science and technology that is perhaps the most important contribution of

[7]Zachary, G. Pascal, Endless Frontier: Vannevar Bush, engineer of the American Century, The Free Press, 1997.

[8]Vannevar Bush, "Science: The Endless Frontier," United States Government Printing Office, 1945, `http://www.nsf.gov/od/lpa/nsf50/vbush1945.htm#summary`

his essay.

Bush divides research into two categories. Basic research is “performed without thought of practical ends.” The other category is applied research, and it encompasses all other research that provides “complete answers” to important practical problems. Bush believed that basic research was crucial for a nation, since “it creates the fund from which the practical applications of knowledge must be drawn.” Thus, he argues that the possible range of applied science is dependent upon the fundamental knowledge available. In other words, technology emerges as a product of “applied science,” and then contributes to social change in a linear succession.[9]

The linear model provides a clean heuristic for understanding the development of science and technology, and held particular sway in the 1950s and 1960s. However, scholars have complicated the picture of the development of science and technology since Bush’s original publication. Analysis of the linear model led to the development of theories of hard technological determinism. In this theory, technology is an autonomous agent and develops independently of social and political forces. However, technology itself creates the social structure and patterns of organizations for human behavior exclusively— humans adapt to the changing technology around them without influencing it.

This exclusive role of technology was not entirely accepted by scholars. A more general investigation of the forces that directed the development of basic research

[9]Ibid.

and innovation was taken up by economists, led by Jacob Schmookler, starting in the mid-1960s.[10] He developed two possible notions of the directionality within the linear model, which are today referred to as "technology push" and "market pull." In the former, developments in technology create a "supply" of possible solutions that are developed before determining needs within the marketplace, a concept essentially similar to the theories of technological determinism. The latter idea takes a demand-side view, arguing that market needs provide signals to researchers and inventors, who develop their basic research programs accordingly. Schmookler takes a decidedly market-pull approach in his work, arguing that essentially all basic science is merely a response to market forces.[11]

Other economic historians criticized such a strong demand-side view, most notably Nathan Rosenberg. He critiques the market-pull theory by exploring the differential development of inventions in industry, arguing that it is not just demand forces but also the stock of available knowledge that affects the rate of invention. Rosenberg briefly writes about Charles Babbage and the development of the first computer, which was not a commercial success. Rather than explaining the failure as a consequence of low demand, Rosenberg argues that the "failure to complete this ingenious scheme was due to the inability of the technology of

[10]Schumpeter developed the first studies of technology and economic growth, positing innovation as the crucial element in the capitalism system. While his work mostly predates the post-war developments outlined here, he provides an important intellectual basis for studies in innovation and economic growth.

[11]Jacob Schmookler, Invention and economic growth, Harvard University Press, 1966.

his day to deliver the components which were essential to the machine's success," and thus, "society's technical competence at any point in time constitutes a basic determinant of the kinds of inventions which can be successfully undertaken." Therefore, a social stock of technical knowledge gives rise to new technological innovations, in accordance with the basic linear paradigm.[12]

### 1.3.2 Social Shaping of Science and Technology

As scholars further probed the interactions between science, technology, and society, there was a growing accumulation of examples that did not fit the linear models. Scholars began to argue that science and technology were shaped and even constructed by social forces, reversing the directionality proposed by Bush and the adherents of the linear paradigm. These models remain hotly debated today, particularly over the issue of scientific relativism.

Thomas Kuhn developed the first major study of society's interaction with science. He demythologizes the notion of the objective search for truth in science, arguing that scientists are engaged in "normal science" for the majority of their time. Occasionally, there is an accumulation of examples that do not fit the reigning paradigm in a field, and there is consequently a battle between the keepers of the old model and the vanguard of the new one. The politics over these paradigm

[12]Nathan Rosenberg, "Science, Invention and Economic Growth," The Economic Journal, Vol. 84, No. 333 (Mar. 1974), pg. 105.

shifts thus form society's influence over the evolving database of scientific facts.[13]

Society's interaction with technology has created a rich body of research, of which the theory of the social construction of technology remains very influential. The theory deconstructs the notion that technologies are designed exclusively by technical decisions, but rather that societal factors often play a paramount role. This methodology was first developed by Wiebe E. Bijker and Trevor J. Pinch, who looked at the societal factors that shaped the development of the bicycle.[14] Another prominent example is the development of missile targeting systems analyzed by Donald MacKenzie. He shows how different groups within the defense community had varying levels of influence over the construction of the ballistic missile targeting program. Thus, the final product was less about the fitness of different technical solutions and more about the changing web of politics surrounding the project.[15]

### 1.3.3 Contextual Models

The increased understanding of different factors affecting innovation has led to the development of more sophisticated models of research that take account of all the directions between the three major components. These "contextual"

[13]Thomas Kuhn, The Structure of Scientific Revolutions, University of Chicago Press, 1962.

[14]Bijker and Pinch, "The Social Construction of Facts and Artefacts: or How the Sociology of Science and the Sociology of Technology might Benefit Each Other," Social Studies of Science, Vol. 14, No. 3 (Aug. 1984), pg. 399-441.

[15]Donald MacKenzie, "Inventing Accuracy," MIT Press, 1990.

models place science, technology, and society in a network of mutual influence, thus establishing the importance of all six possible directions. As opposed to hard technological determinism, the theory of soft technological determinism argues that technology is a primary but not exclusive agent of social change, and it generally fits within this contextual framework.

More usefully for this study, Etzkovitz and Leydesdorff have developed the theory of the "triple helix" to describe the relations between universities, industry and the government. While the three types of institutions are generally described as being part of a triangle, the triple helix model takes as a basis the differential approaches of the three groups and adds elements of co-evolution (generating the ever-evolving helix). Thus, developments in one of the three institutions changes the trajectory of all three, and it is the constant adaptation of the system to these new developments that explains regional and national innovation systems.[16]

Etzkovitz has further developed these notions in analyzing the development of "entrepreneurial science" at MIT and Stanford. He argues that universities are increasingly adding the capitalization of knowledge to their missions, complementing research and teaching and representing the next stage in the development of these institutions. He traces the development of this model to MIT, which pioneered the industry-facing university and the concept of venture capital that is an important

[16]Universities and the Global Knowledge Economy: A Triple Helix of University-Industry-Government Relations, Ed. Henry Etzkovitz and Loet Leydesdorff, Pinter, 1997

component for innovative regions. MIT's model was later transferred to Stanford in the form of Frederick Terman, who became Stanford's provost and had received his PhD from MIT.[17]

## 1.4 Approaches to Regional Innovation and Computing

Before exploring the major research approaches to computing and regional innovation, some historical context is necessary. Computing has fundamental connections with mathematics, but the notion of a computer as a calculating machine is generally attributed to Charles Babbage. He was a mathematician at Cambridge who developed the idea of a "difference engine" in 1821 that could build mathematical tables with less errors than humans. In the same era, the mathematician George Boole developed a logical calculus for binary values that today forms the basis of nearly all mathematics on computers.[18]

Mathematicians continued to hold a crucial role in the development of computing in the years before World War II. Among the most important figures in computing is Alan Turing, a mathematician at the University of Cambridge who

[17] Henry Etzkovitz, MIT and the Rise of Entrepreneurial Science, Routledge, 2002.

[18] There are numerous references available on the early era of computing. The Charles Babbage Institute of the University of Minnesota provides immense bibliographic resources. This section is from the review by Gerard O'Regan, A Brief History of Computing, Springer, 2008.

developed the notion of a Turing machine, a hypothetical computational device. Turing proved that these machines could represent all calculations possible on a computer, and thus, they provided a theoretical limit on the power of computation. Independently of Turing, Alonzo Church, a mathematician at Princeton University, developed a similar limit through the development of lambda calculus. The combined Church-Turing Thesis provides the means of converting between these different notions of computing, and continue to represent the core of computability theory.[19]

These theoretical developments took place just as the growth of the region today known as Silicon Valley was beginning. During the early years of the twentieth century, the peninsula south of San Francisco was perhaps more notable for its lack of industry than for scientific innovation. The development of university-industry relations at Stanford in the 1930s, however, began a process of industrialization, particularly in radio. The computing industry was generally concentrated in New England, and its effects on the area known as Silicon Valley would not become significant until the 1950s and 1960s. Since then, the region has been one of the preeminent innovation hubs in the world.

[19]Ibid.

### 1.4.1 Historical Institutional

Historical institutional approaches take as their subject an organization within a region's research system and analyze its web of influences. Such approaches provide an important perspective by allowing a high degree of synthesis and integration. However, the method can provide a fragmented picture of the relations between science, technology, and society since organizations are often products of local forces, and translating findings to other institutions can be difficult. This section looks at several major studies in this area, saving those analyzing Stanford as an institution for a later section.

Developing a history of Silicon Valley has proven difficult due to its diversity, but Christophe Lécuyer has written a technically-sophisticated and nuanced account of the changing composition of companies and industries that underpinned the economy of Silicon Valley. He follows the development of each new industry by analyzing prominent companies, including Eitel-McCullough, Varian Associates and Shockley Semiconductor. He finds that the firms benefited from a close collaboration with Stanford, a culture well-adapted to the needs of innovative enterprises, strong connections between manufacturing and research programs, and defense procurement policies that benefitted the Valley's firms over their competitors in the East.[20]

[20] Christophe Lécuyer, Making Silicon Valley, MIT Press, 2005.

Margaret O'Mara analyzes federal policies to compare the different trajectories of Silicon Valley, Philadelphia and Atlanta as regional innovation hubs. One of her major areas of focus is the use of dispersal policies by the Pentagon in response to the atomic threat from the Soviet Union. O'Hara argues that the military, through its funding policies, encouraged the deconcentration of urban centers by supporting the development of more diffuse industrial regions that could withstand nuclear attack. The theory is novel, and its emphasis on the importance of geography in political economic studies of regional innovation hubs is worthy of further study. However, the theory suffers from a level of reductionism that was handled far more deftly in Lécuyer's analysis.[21]

The effects of U.S. government policies on the development of computing and Silicon Valley are of obvious interest, and several scholars have analyzed government agencies and the politics surrounding their policies. William Aspray and Bernard O. Williams studied the National Science Foundation and its programs to support the development of scientific computing. In the three decades following the war, the foundation sponsored grants for universities to buy computers, totaling millions of dollars. By the end of the 1960s though, the foundation increasingly desired to focus on the development of a theoretical discipline of computer science, and eventually ended its computational facilities program in 1970.[22]

[21] Margaret P. O'Mara, Cities of Knowledge: Cold War Science and the Search for the next Silicon Valley, Princeton University Press, 2005.

[22] William Aspray and Bernard O. Williams. "Arming American scientists: NSF and the

The foundation's desire to support pure science is heavily analyzed by Daniel Lee Kleinman, who explores the politics surrounding the agency's establishment. One model was developed by Vannevar Bush, who believed that the agency should focus exclusively on basic science and create an elite, meritocratic system of funded research. The other approach was most vigorously argued by Harvey Kilgore, a Democratic senator from West Virginia. He desired a system with more applied science and a greater geographical distribution of research funds. Kleinman demonstrates convincingly that Bush and top industrialists at the time worked together to secure their vision for the organization, and thus social and political factors held a tremendous role in the development of the new agency, and by extension, the nature of science in the postwar period.[23]

Despite the impact of the National Science Foundation, it was the Department of Defense that likely had the largest impact on the growing use of the computer. Arthur L. Norberg and Judy E. O'Neill have shown that the Defense Department's Advanced Research Projects Agency and its Information Processing Techniques Office played crucial roles in the transformation of computing. Led by a leader with strong vision of the potential of computing, IPTO transformed the development of time-sharing and graphics, which led to a fundamental change in industry's

provision of scientific computing facilities for universities, 1950-1973." Annals of the History of Computing, Vol. 16, No. 4 (Winter 1994), pg. 60-74.

[23]Kleinman, "Layers of Interests, Layers of Influence: Business and the Genesis of the National Science Foundation." Science, Technology, and Human Values, Vol. 19, No. 3 (Summer 1994), pg. 259-282 and Kleinman, Politics on the Endless Frontier, Duke University Press, 1995.

approach to the development of computing systems. They explore the relations between the Pentagon's needs and those of academia, and how specific funding and research policies shaped the course of computing in academia.[24]

One final strand of historical institutional research that is relevant to this study is the theme of big science. The history of science has classically been one of the independent scientist developing and testing theories individually, with perhaps a few assistants. Starting in the years prior to World War II though, there was a growing trend toward large research labs with dozens if not hundreds of personnel. Peter Galison and Bruce Hevly have edited a volume that explores the implications of these changes as well as the policies that led to this concentration. The diverse essays provide multiple perspectives on the rise of big science as an institutional characteristic.[25]

### 1.4.2 Historical Cultural

Historical cultural analysis takes as its subject a group of people with sociologically similar characteristics and explores how a particular cultural background affects the direction of a region or institution. Within the literature on Silicon Valley, AnnaLee Saxenian conducted one of the first and most celebrated com-

[24] Norberg and O'Neill, Transforming computer technology: information processing for the Pentagon, 1962-1986, Johns Hopkins University Press, 1996.

[25] Big Science: The Growth of Large-Scale Research, ed. Galison and Hevly, Stanford University Press, 1992.

prehensive ethnographic studies, comparing the region and its dynamics to those of Route 128, the high-tech corridor near MIT. She argues that differences in firm formation and structure are instrumental in the varying levels of success of the two regions. Firms in Silicon Valley are smaller and less vertically-integrated compared to their Eastern competition, and there is more camaraderie between engineers that facilitates greater competition and velocity of information.[26]

However, Saxenian's work suffers from several methodological problems that limits its utility in understanding the region. The emphasis on interviews with business executives and engineers provides an interesting perspective on corporate culture, and few will contest that the culture in the Bay Area is different from that in Massachusetts. However, Saxenian's evidence is insufficient to place firm culture and structure as the major basis for regional development. The primary problem is one of causality: did the culture change the industries or did the industries create the culture? Saxenian reduces the relationship to an almost linear level, but further evidence suggests the two co-evolved, complicating the history far more than she addresses.

Lécuyer takes a more nuanced cultural approach, integrating biographical details of the business executives and engineers of the region's most notable companies with the corporate structure that forms within them. He finds that the engineers of the first major companies shared similar stories: a middle class up-

[26] AnnaLee Saxenian, Regional Advantage, Harvard University Press, 1994.

bringing, a desire to participate in the rise of radio, and a social ethic that emphasized community and libertarianism. He argues that this culture is an important factor of the development of the culture's of these firms, but not a sufficient one.[27]

Outside of regional development, significant work has been done on analyzing the connection between the counterculture movement and the rise of computation in Silicon Valley. Fred Turner has written a definitive account of this group, focusing on the story on Stewart Brand and a group of people he calls the "new communalists." He argues persuasively that much of the culture of computation, such as decentralization, libertarianism, and optimism toward technology, are merely manifestations of the culture of people like Brand. Furthermore, this culture helped to facilitate the creation of the networks that today underpin the organizational structures found in so many computer firms.[28]

### 1.4.3 Network Analysis

Network analysis is a newer approach to studying the rise of regional innovation hubs and focuses on a defined unit of relationship between entities in the system, which are then systematically tracked over a period of time. Given the right dataset, it can offer persuasive evidence of how and when networks develop within regional innovation systems. However, the approach often suffers from its

[27] Christophe Lécuyer, Making Silicon Valley, MIT Press, 2005.

[28] Fred Turner. From Counterculture to Cyberculture: Stewart Brand, the Whole Earth Network, and the Rise of Digital Utopianism, University of Chicago Press, 2006.

equivalence of relationships (for instance, considering each patents as one unit regardless of actual quality or economic worth).

This approach developed from the work of Walter W. Powell, who found that the classic market-hierarchy spectrum of economic organization does not fully fit firms where tacit knowledge and experience form important sources of capital. Powell argues that network forms of organization can transfer knowledge into action more quickly and allow for sustained cooperation between firms. He applies this approach to a host of different industries, finding that high tech start-ups in areas like Silicon Valley are very similar in their networked organization as craft firms in Italy.[29]

Jeanette A. Colyvas and Powell applied network analysis to the case of academic entrepreneurship in the life sciences at Stanford. They find that entrepreneurship at the university grew incrementally over the course of three decades. In the early years, only senior faculty with tenure were willing to engage in industrial activities, their reputations having already been secured. As others in the the life sciences witnessed their success, they too began to engage in academic entrepreneurship. The two scholars find that network effects were particularly important factors in an individual's likelihood of engaging with industry. Those with more publications were significantly more likely to secure patents, and students

[29] Walter W. Powell, "Neither Market Nor Hierarchy: Network Forms of Organization." Research in Organizational Sociology, Vol. 12 (1990), pg. 295-336.

and younger faculty were more likely to be entrepreneurial if they were working with senior faculty.[30]

Saxenian used network analysis as part of her comparative ethnographic study, but scholars have also taken a more quantitative approach to network analysis. Lee Fleming has applied a network approach in studying the development of regional economies by looking at data of patent authorship and citations. Olav Sorenson and Fleming analyzed the value of academic scientific research in regional networks by looking at different groups of patents. Analyzing the data, they find that patents which cite any publication — whether a journal article or a press release — increase their future citation counts. Thus, the increased value of a patent citing the academic literature can be mostly attributed to increased communication rather than increased quality.[31]

## 1.5 Historical Development of Computer Science

A core part of this study analyzes the academic politics of the Stanford faculty and their approaches to the developing discipline of computer science. Throughout its early years, computer science was a hybrid construction. One side provided computing resources for other disciplines in the university, while another side di-

[30] Colyvas and Powell, "From Vulnerable to Venerated: The Institutionalization of Academic Entrepreneurship in the Life Sciences." Research in the Sociology of Organizations, Vol. 25 (2007), pg. 219-259.

[31] Sorenson and Fleming, "Science and the Diffusion of Knowledge." Research Policy, Vol. 33, No. 10 (Dec. 2004), pg. 1615-1634.

rected the theoretical developments of computer science as a field. Scholars in recent years have increasingly focused on the development of the discipline of computer science, although coverage of it remains limited.

Atsushi Akera has developed a theoretically rigorous synthesis of the rise of academic computer science as part of his study on the pluralism of computation in the Cold War era. He develops the notion of an ecology of knowledge pioneered by Charles Rosenberg to show how the tension between military applications, commercial goals and academic desires shaped the direction of computing. On university campuses, this tension was manifest between the academic staff of the discipline and the service staff of university computational facilities. Akera shows the struggle between these two at MIT and the University of Michigan over the development and deployment of time-sharing computers, a debate that eventually led to their "disintegration."[32]

The importance of the military is not absolute, and Paul Ceruzzi has explored the connections of computing to science and engineering businesses. He looks at the evolution of different components of a computer system, including at the hardware level with core memory and at the software level with operating systems. He investigates the role that computers have taken in information processing, attempting to define what a computer is and how it has changed over the post-

[32] Atsushi Akera, Calculating a Natural World, MIT Press, 2008.

war period, providing a wide-ranging perspective on the rise of computer science.[33]

Ultimately though, the development of academic computer science was led and constructed by faculty at major research universities. Much of the development of computing in the 1960s can be traced to research at MIT centered around Project Whirlwind, which developed one of the first computers with real-time displays. Kent C. Redmond and Thomas M. Smith studied the pressures between the MIT administration of the project, notably Jay Forrester, and the Office of Naval Research. Forrester pushed the project hard, ignoring budget projections and focusing exclusively on expanding scientists' knowledge of computers. While the work relies perhaps too heavily on oral histories with the project leadership, it provides an insightful account of the different goals of universities and the military.[34]

Recently, Ensmenger has looked into the development of the discipline of computer science, analyzing the qualities of people who entered the field. He writes that the need for academic legitimacy was a crucial element in the direction of computer science departments, and this concern caused departments to focus on theoretical concepts (especially the algorithm) as a means of building a defined field of inquiry with open problems and clear research directions. He argues that this increasing theoretical basis assisted academic departments, but led to a widening gap between the science and the applications of computer science.[35]

---

[33]Paul E. Ceruzzi, A History of Modern Computing, 2nd ed., MIT Press, 2003.

[34]Redmond and Smith, Project Whirlwind : the history of a pioneer computer, Digital Press, 1980.

[35]Nathan Ensmenger, The Computer Boys Take Over: Computers, Programmers, and the

Ensmenger's study provides interesting evidence on the people who worked on computers during the rise of computer science, but it lacks a more encompassing geographical approach. The focus is primarily on the East Coast schools — most heavily MIT — and this limited range of the work hinders its wide utility. In fact, the story at Stanford was quite different, as this study will show — the department simultaneously increased its vigor in the theoretical fields while building important and quickly-growing connections to industry.

## 1.6 History of Stanford

Stanford University was founded in 1891 by Jane and Leland Stanford as a memorial for their son, who died from typhoid. Leland was a railroad magnate and a former governor of California, and the two donated 10,000 acres of land on the peninsula south of San Francisco to be used as a permanent home for the university. Stanford's first president, David Starr Jordan, served more than twenty years, and oversaw the rebound of the university from the devastation of the 1906 San Francisco earthquake. The event ushered in an austere period, and an ongoing struggle for financial security at the university would continue for several decades.

After the stock market crash of 1929 and the economic depression that followed,

Politics of Technical Expertise, MIT Press, 2010.

income for Stanford fell precipitously, putting the school on even more precarious financial ground than before. Stanford's on-going financial difficulties had harmed its ability to recruit faculty, and by the 1930s, college rankings did not place Stanford among the top ten schools nationwide. There was an acceptance by the president, Ray Lyman Wilbur, that the university was facing deep problems in its basic operations. To counter the decreases in income facing universities, the federal government created programs to increase funding for research. However, these programs were widely rejected by universities, including Stanford, for fear of government intrusion in private universities.[36]

This environment created a proving ground for Frederick E. Terman, a professor of electrical engineering who by the 1930s was chair of the department. Terman was the son of Lewis Terman, a child psychologist who invented an IQ test, and Fred Terman had studied under Vannevar Bush at MIT in the 1920s. Observing the financial situation of the school, Terman was deeply concerned at the direction of the university. As chair of Electrical Engineering, Terman spearheaded the creation of industrial partnerships, realizing an opportunity to secure additional funding. Thus, the department began a long and vital relationship with local industry. It was also around this time that Terman helped to train William Hewlett and David Packard, perhaps the most notable example of the kind of university-

[36]One of Stanford's trustees at the time was Herbert Hoover, who opposed much of the expansion of the federal government during this period. Rebecca S. Lowen, Creating the Cold War University, University of California Press, 1997.

industry partnership desired today.[37]

Bush's impact on science policy is certainly important, but it is his interests in computing that make him particularly relevant to the story of computer science. By 1931 he had developed a "differential analyzer," a mechanical computer that could give numerical solutions to differential equations. The device captured the imagination of the public, and leading scientists were very optimistic about the future of mechanical calculators. Bush's interests in computing were vast, and his predictions about a machine that could retrieve information created metaphors that apply to the internet today.[38]

Terman remained close to Bush throughout their relationship, and he used the expanded funding from the federal government in the postwar years as a means to subsidize the growth of new and powerful departments at Stanford. The funding was largely derived from increased defense spending following the Korean War, and much of this funding was of an applied nature. This approach, which Terman referred to as "steeples of excellence," had several different components. First, the university should emphasize areas of research that had strong federal funding and wide contacts in industries. Second, he often encouraged the hiring of several faculty members in the same academic area, with the goal of building a national center in a sub-field critical to the future development of the discipline.[39]

[37]C. Stewart Gillmor, Fred Terman at Stanford, Stanford University Press, 2004.

[38]G. Pascal Zachary, Endless Frontier: Vannevar Bush, engineer of the American Century, The Free Press, 1997.

[39]Ibid. and Rebecca S. Lowen, Creating the Cold War University, University of California

It is in this period of growth that scholars often analyze the historical institutional development of Stanford and Silicon Valley. In his work on the subject, Stuart W. Leslie explores the changing nature of research at Stanford and the relationship between the university and military research grants. He is relatively pessimistic about these developments, lamenting the transformation of universities from being independent basic science organizations to directed applied agencies of the government. Due to their large grant programs, the military was able to direct research activities, and largely "defined what scientists and engineers studied, what they designed and built, where they went to work, and what they did when they got there."[40] His criticism is valid, although perhaps overstated, particularly in the context of the development of computer science where defense funding led to significant civilian applications.

Lowen's work is the most intellectually similar to this study's approach and sensibility. As she emphasizes, the military held a crucial role in the development of engineering departments at Stanford including Electrical Engineering. While her work does not extend into the growth of computer science, many of the same issues arose, including the balance between basic and applied research. Terman's approach to computer science was keeping with these developments, and much of the core debate over the identity of computer science as either a service to the

Press, 1997.

[40] Stuart W. Leslie, The Cold War and American Science, Columbia University Press, 1993, pg. 9.

university or an academic discipline derives from these problems.

## 1.7 Stanford Computer Science: Study Outline and Source Notes

The first notion of computer science at Stanford developed in the Mathematics department under the direction of George E. Forsythe and John McCarthy, both numerical analysts. Forsythe was a mathematician, with great interests in solving problems numerically. This interest began during the war when he served as a meteorologist, but it was truly developed at UCLA, where he served at the Institute for Numerical Analysis of the National Bureau of Standards. He had access to a computer in this position, and began a life-long mission to use the power of computing to solve important mathematical problems.

After joining the department in 1957, Forsythe worked with Herriot to quickly develop computer science into its own discipline. Computer science was soon provided its own division within the department, allowing Forsythe a level of independence for the burgeoning area of study. These early years were tough for the division. Faculty billets were shared with the Mathematics department, ensuring a constant friction over staff. Furthermore, the development of computer science as a discipline brought its research program away from the work conducted by other mathematicians, generating important discussions on the utility and legitimacy of this new discipline. Eventually, these disagreements would cause Forsythe and the Computer Science division to leave the Mathematics department and create their own independent division at the end of 1963.

Despite these issues of academic legitimacy, the new division grew rapidly, increasing in staff as Forsythe built alliances with other departments on campus through joint appointments. The expansion of the division's graduate program ensured a strong incoming class of doctoral students, who were top in the field. The division's growth led to the university administration granting full department status on January 1, 1965. However, the financial pressures on the department continued to grow as high inflation and university budget cuts constrained its expansion. Through a range of programs with industry, Forsythe developed new sources of income which allowed for new faculty growth and greater prominence. Forsythe would lead the department until his early death in 1972 from cancer at age 55.

This study is divided into three chapters grouped thematically that together complicates and enhances our understanding of the pathways universities take in engaging with regional innovation hubs. Chapter two considers the politics of computer science and particularly artificial intelligence within the context of the academy. It focuses on the debates surrounding the tenure cases of artificial intelligence researchers John McCarthy and Marvin Minsky as well as William F. Miller, a physicist with interests in computing. This chapter complicates our understanding of the history of Stanford's links to innovation, showing that different constituencies within the university were widely varying in their desire to engage with the development of a new academic discipline and industry. The archival material in this area is particularly rich, and allows for a close dialogue between the actors.

Despite these protests against the development of the Computer Science division, it was granted department status and became one of the top programs in the nation. Chapter three analyzes the university environment to determine what institutional factors allowed the department to overcome this resistance. This chapter argues that cultural factors of the faculty and administration played an instrumental role in the university's continued support for growth within the field. The financial insecurity experienced by the department throughout the decade forced a bureaucratic creativity and efficiency very much in the style of a twenty-first century start-up company. The administration itself did little to constrain Forsythe, even when he spent more money than budgeted. Its active and passive facilitation ensured that the department had few bureaucratic hurdles to retard its development.

These cultural factors led to further growth in the department, but they do not completely explain the desire to engage with industry. Chapter four explores the mutual relationship of the Computer Science department and industry. Major corporations in computing, particularly IBM, assisted in subsidizing the costs of developing the Computer Science department, in exchange for early access to research and the publication of new tools for their company's computer systems. The need for further funds encouraged the development of new venues to engage industry, and the chapter concludes with an exploration of the Honors Co-Op program and the Computer Forum that led to the first formation of networks between the department and industry.

Archival materials for this study come from the Stanford University Archives, and consist of documents primarily from the George Forsythe as well as William F. Miller, Frederick E. Terman, Richard Lyman, J.E. Wallace Sterling, Edward A. Feigenbaum, Joshua Lederberg and the School of Humanities and Sciences collections. There has not been a study published on the history of computer science using these archival materials. Footnotes include the indexing of these documents starting with collection number and ending at folder number.

# Chapter 2

# Academic Politics and Legitimacy

The construction of new disciplines within the academy provides rich insight into the politics of knowledge. An academic discipline is the intellectual and bureaucratic categorization of a domain of human knowledge, and is composed of its practitioners, modes of communications (such as journals and conferences), and database of acquired knowledge.[1] The modern American research university includes several prominent features, but two of the most important are its relatively decentralized structure based around these academic disciplines and the self-autonomy of the faculty members to determine the course of their fields.

These disciplines are not static, but adapt as new domains of knowledge are created. The classic quadrivium of arithmetic, geometry, music and astronomy has gradually expanded to encompass a large range of disciplines loosely grouped into the natural sciences, social sciences and the humanities. Today, it is not unusual for universities to have dozens of departments organized into several schools. While there has been a long intellectual history about the possibility of these disciplines eventually unifying, the general trend has been for further branching and fragmentation, with interdisciplinary programs acting to overcome some of these gaps.[2]

The terrain of fragmentation is constructed through a mutual shaping between the institutions that support knowledge production and the people that populate

[1] In this study, "field" and "area" will be considered synonyms of academic discipline.

[2] A readily readable account of this history is provided by E. O. Wilson, Consilience, Vintage Books, 1998.

them. The peculiar features of the modern university create an environment in which social and political factors can play an instrumental role in the direction of this branching process. A new discipline may receive resistance due to an intellectual disagreement over its definition as a domain of knowledge, or simply due to the power held by administrators. Thus, the creation of a new field represents an important area to study the politics of knowledge, or the ways in which social and political forces shape the use, dissemination and discovery of knowledge.

History plays a crucial role in the development of new disciplines, including computer science. Starting in the immediate postwar period after 1945, there was an increasing supply of computation to researchers and practitioners due to the quickly developing power of computers.[3] This increasing capacity allowed for a greater range of potential calculations, and notably affected the field of numerical analysis, the study of methods to solve mathematical problems for which analytical solutions are not possible.[4] Computer science was partly constructed out of numerical analysis, and this derivation is particularly important in the course of its development at Stanford.

Starting in the late 1950s, there was a growing realization among computer researchers that a discipline existed outside of the currently accepted domains of

[3]The term computer is used quite loosely to encompass the varied instrumentation available throughout this era.

[4]It is important to recognize here the role that theories of technological determinism play in the development of computer science. The increasing computational power played a necessary role in the development of the discipline, but it was not, I contend, a sufficient condition for the rise of the field

knowledge. The pathways from the current disciplines to computer science varied by institution, but here we focus on the Stanford case. George Forsythe, the father of computer science at Stanford, was a numerical analyst and a faculty member in the Department of Mathematics. Almost immediately after joining Stanford in 1957, he set out to construct this new discipline, but not without difficulty.

The branching of computer science from mathematics created significant tension due to several concerns. First, as a new field, computer science faced the burden of developing the institutions and organs needed for an academic discipline. Computer science did not have the typical elements, like journals, that would formalize and rationalize the discipline, and thus, it was difficult in the early years to find support among faculty members, particularly during tenure cases.

Another source of tension was the intrinsic nature of computer science, which prevents the field from being clearly defined as either a basic or applied science. The discipline has constructions like the Turing machines, the discovery of which is one of the most important intellectual developments of the 20$^{th}$ century. At the same time, it has very prominent applications through its utility in programming computers to perform tasks. This divide is at the heart of the faculty debate presented in this chapter. Skepticism about computer science was common, especially among faculty in the natural sciences who perceived the discipline to be closer to engineering.

However, it was not just external faculty who debated the definition of computer science, but computer scientists across the country as well. One side argued that computer science should facilitate research in other fields, and should thus be considered a service to the university. This conception was common among researchers funded by university computation facilities. Others in the field argued that computer science was its own academic discipline and domain of knowledge, and thus should be considered an equal in the university. Unsurprisingly, this perspective came from faculty who desired an academic career studying in the area.

A fundamental component of this debate, and the politics of knowledge more generally, is the definition and application of academic legitimacy. Legitimacy within the academy is essentially the acceptance of a discipline by the faculty of other disciplines, as well as generally by the school administration. However, there are additional components to consider. To be a discipline requires practitioners, modes of communication and a database, and there may be varying disagreements on each of these parts. For example, should a memo sent through the mail be considered a "publication"? What should the qualifications be for a faculty member in a field that does not have doctorate programs?

This study engages with this broad intellectual framework by analyzing the history of the development of the Computer Science department at Stanford. Computer Science developed out of the Mathematics department, and it is here that the first frictions between the new field and established disciplines took place. As Computer Science gradually expanded in size and independence, critical attention from faculty in other disciplines became more palpable. Nowhere was the conflict over the field more evident than in the debates over faculty appointments in what was first the Computer Science division and then later, the Computer Science department. While faculty outside the field had little control over the autonomous administrative unit, their input was a critical element of the tenure process.

This chapter analyzes and contextualizes the conflicts over the legitimacy of computer science primarily by analyzing the tenure cases of John McCarthy, and particularly Marvin Minsky and William F. Miller. Due to the richness of the archival materials, these cases provide an excellent episode to analyze the politics of knowledge of computer science by placing different actors in dialogue with one another. The analysis will show that influential faculty were opposed to the development of computer science over concerns that its applied character did not belong in the School of Humanities and Sciences (H&S). However, organizational flexibility on the part of Stanford, particularly by the dean of the H&S school and the university provost, provided crucial support in the discipline's formative years. Their "gamble" would eventually pay off as Stanford developed a reputation as one of the leading centers of computer science in the United States.

## 2.1 Numerical Analysis and Computer Science

Today, numerical analysis is defined as the study of algorithms for the problems of continuous mathematics.[5] Its practitioners focus on the development of approaches for solving problems without analytical solutions. The emphasis on continuous mathematics is important, as continuous functions lend themselves to iterative methods of solution.[6] These iterative methods, which include gradient methods and Newton's method, are complemented by direct method approaches that can reach the precise answer in a finite number of steps. Such methods as QR factorization, the simplex method and the Householder transformation to calculate the singular value decomposition are among the most well-known tools developed in the field.

To get a flavor of the sort of problem that is solved using numerical approaches, consider developing a best fit line for a set of data. The line is linear, and therefore it only has two parameters —the intercept and the slope. The line can be translated vertically by changing the intercept, and the line's direction can be changed by adjusting the slope parameter. However, there could be hundreds if not thousands

[5] Lloyd N. Trefethen, "The Definition of Numerical Analysis," SIAM News, Nov. 1992.

[6] Iterative methods generally do not lead to a precise answer, but they approach the answer one small step at a time, and thus arrive arbitrarily close to the precise answer.

of points on the graph, and thus, it is likely impossible for a line to touch them all. Numerical methods are used to build the line closest to all of the points by reducing the total combined error of the distance between the points and the line. One direct approach is the method of least squares, but we could also consider an iterative approach that would slowly vary the parameters to steadily decrease the total error.

The highly-developed nature of the field today is vastly different from the terrain viewed by numerical analysts in the immediate postwar period. Many of the common algorithms and approaches used today had yet to be developed, and there was difficulty in implementing many of the methods due to the limits of human mental faculties and time to calculate iteratively. The rise of computers would fundamentally alter this situation. The development of computation power in the 1940s and 1950s provided a new capability to researchers, allowing them to make quick calculations that are at the core of numerical analysis.

It was within this milieu that George Forsythe developed his career. He received a PhD from Brown University in 1941 and became a meteorologist during the war, a position that demonstrated to him the value of numerical solutions to problems like simulation.[7] Starting in 1948, he began working at the Institute for Numerical Analysis of the National Bureau of Standards at UCLA. That position afforded

[7] James Varah, "The Influence of George Forsythe and His Students" part of The History of Scientific Computing, Ed. Stephen G. Nash, ACM Press, 1990.

Forsythe access to a computer, and he quickly developed a sense of the intellectual power that computation and programming could offer. As his experience increased, Forsythe began to encourage mathematicians to focus more on the development of computation, arguing that the possibilities of the technology were immense for the development of the field. He had a difficult time convincing mathematicians of that goal, a critical part of the later story at Stanford.[8]

This hesitation by mathematicians was partly due to the difference in stature of the two fields — mathematics and computer science — at the end of the 1950s. Numerical analysis is intimately connected with the development of mathematics. One of its core methods was developed by Newton, who also developed calculus. Despite the development of core theoretical concepts like the Turing machine, computer science lacked the storied history that provides a source for academic legitimacy. The scope of computer science is far larger as well, incorporating not just algorithmic development but also issues of theoretical complexity, software design, natural language processing, artificial intelligence and other domains. Numerical analysis thus also benefits from greater coherence due to its more restricted domain of research. That coherence was also a major concern of mathematics, as we will soon see.

[8] Donald E. Knuth, "George Forsythe and the Development of Computer Science," Communications of the ACM, Vol. 15, No. 8 (Aug. 1972), pg. 721-727.

## 2.2 Computer Science and Mathematics

Forsythe joined the Stanford Mathematics department in 1957 as a full professor, joining John Herriot as a numerical analyst. Herriot was among the first of the leaders of computation at Stanford, and the two men immediately began to consider approaches for developing the field of computer science on an educational and intellectual level within the department. In the years before 1961, there was no official administrative structure for computer science, although Forsythe did formulate a sub-field of sorts within the department by 1959. All decisions regarding the academic side of computer science in these years were passed through David Gilbarg, the chair of the department. Gilbarg's interests were in algebraic number theory early in his career, but his work in World War II led him to focus on nonlinear partial differential equations and fluid dynamics for the remainder of his career.

When Forsythe arrived, the differences between the area now defined as computer science and the traditional field of mathematics were relatively few. Mathematics hired Forsythe to add strength in numerical analysis, and he strongly believed in the utility of numerical approaches, which he considered to be the next stage in the development of mathematics. He urged his colleagues that a mathematics education should include at least a basic background in using computation.[9]

[9]Donald E. Knuth, "George Forsythe and the Development of Computer Science," Communications of the ACM, Vol. 15, No. 8 (Aug. 1972), pg. 721-727.

The university administration was also enthusiastic about the new field. Albert Bowker, a statistician who was an associate dean in the School of Humanities and Sciences, discussed the formation of an autonomous division for the field from the very start of its formation within Mathematics.[10] By 1961, the discussion had moved to the issue of logistics, and how such a division would be formed and operated within H&S. Gilbarg was not actively a part of these conversations despite being chair of the department, and felt with some surprise that the "thinking on this matter has progressed substantially, and much farther than I realized."[11]

Gilbarg informed the H&S dean, the philosopher Philip Rhinelander, of his basic approval. Gilbarg was relatively enthusiastic about the creation of an autonomous division for computer science, arguing that it would provide coherence and would be easier to expand the faculty. Furthermore, he argues that if the field was to become a department, then moving to an independent division would be an appropriate first step. Even at this point, just two years after the creation of the sub-field, he notes that there was increasingly a divergence between mathematics and computer science, and that an independent division would fit the diverging nature of the two fields. "The new faculty contemplated for the Division," he wrote, "would not ordinarily be appropriate as members of the Mathematics De-

[10]The idea of an autonomous division within Mathematics was a bureaucratic construction. The basic design was to place Forsythe as head of the division with his own budget, but with the chair of Mathematics continuing to hold final administrative authority. The change allowed Stanford to argue that it had an autonomous Computer Science unit.

[11]Gilbarg to Rhinelander, "Division of Computer Science," 9 Jan. 1961, H&S Files, SC36/89-114/8/"CS: 62-63."

partment."[12]

Not surprisingly, Gilbarg came down squarely in support of the approach taken by non-numerical mathematicians. "I admit to some qualms concerning the scientific quality of the work in Computer Science – at least compared with that in the traditional scientific disciplines. I refer primarily to the technological rather than fundamental character of much of the work."[13] Nonetheless, his more immediate concerns were pragmatic, consisting of requirements for transferring the faculty slots for Forsythe and Herriot into the new division and for separating the new budget. Tellingly, one of his conditions was that faculty appointments within the division should require his approval, creating an administrative review that would greatly increase the tension between these two fields in the coming years. However, there was little desire at this point to negotiate these requirements, and the conditions were accepted a few days later by Patrick Suppes, a philosopher of science and an associate dean of H&S leading to the creation of an official division within the Mathematics department.[14]

The heart of the issue is the unique economics of universities. Faculty slots are highly prized, since they are permanent budget outlays to a department and at Stanford, offered the possible benefit of tenure to their recipient. Since Computer

[12]Ibid.

[13]Ibid.

[14]The academic backgrounds of these deans is important to this story, and receives fuller treatment in Chapter 3. Suppes to Gilbarg, "Division of Computer Science in the Department of Mathematics," 1 Feb. 1961, H&S Files, SC36/89-114/8/"CS: 62-63."

Science was a part of Mathematics, the two programs shared faculty slots, and a zero-sum mentality developed over each new slot. In this case, the bureaucratic structure increased this divisiveness because the chair of the Mathematics department was the chief evaluator of faculty nominations from the division. The reviews succeeded when interests aligned, but Forsythe's desire to expand into new areas like artificial intelligence would cause a permanent fracture in the relationship.

### 2.2.1 Artificial Intelligence

In 1962, one of the first computer scientists to be nominated for an appointment at Stanford was John McCarthy, a researcher in AI at MIT who had previously coined "artificial intelligence" at Dartmouth.[15] Halsey Royden, a professor of mathematics and a member of the Appointments and Promotions advisory committee within H&S,[16] commented on McCarthy's qualifications to Robert Sears, who was by then dean of H&S. Royden wrote that McCarthy had previously been an assistant professor at Stanford, although he was not reappointed to the position in 1954 due to concerns that he lacked publications and an ability to find his own problems.[17] However, Royden was excited about the future of artificial intelligence

[15]Dartmouth was a major site of Computer Science in this era. John Kemeny, who studied under Alonso Church at Princeton and was an assistant to Albert Einstein, developed the BASIC computer language and would later become president of Dartmouth College.

[16]Royden would become Associate Dean later in 1962, and would be dean of H&S from 1973 to 1981. His membership on the A&P committee is cited from Sears to Gilbarg, "Computer Science Division Appointments," 6 Apr. 1962, H&S Files, SC36/89-114/8/"CS: 62-63."

[17]Royden to Sears, "Possible appointments in the Computer Sciences Division," 6 Apr. 1962, H&S Files, SC36/89-114/8/"CS: 62-63."

research, writing that "this is certainly a very exciting field at the present time, and I feel that it is very important for Stanford to move in this direction."[18]

Like Gilbarg, Royden also perceived a difference between the area of computer science and mathematics. He commented that McCarthy was not strong as a mathematician, but that his sophistication was of "a higher order than is usually shown by people in the field of computer sciences." Royden argued for the appointment by comparing computer scientists to mathematicians in the social sciences, where "there are very few people with established mathematical competence, but where it is important for Stanford to keep abreast of a developing field."[19] In Royden's judgment, McCarthy was the best within machine learning, and thus Stanford should attempt to secure him. Finally though, Royden urged some level of caution, since McCarthy's appointment as a full professor would likely cause some "unhappiness" among the faculty in Mathematics, who would feel that he is receiving "unmerited preference" over others in the department.[20] With the support of Royden, Sears moved forward with the appointment, and officially brought in Gilbarg to the conversation.[21] McCarthy would join the department as a professor later that year.

While there was minor concern over the appointment of John McCarthy in

[18]Ibid.
[19]Ibid.
[20]Ibid.
[21]Sears to Gilbarg, "Computer Science Division Appointments," 6 Apr. 1962, H&S Files, SC36/89-114/8/"CS: 62-63."

artificial intelligence, it would be the proposed appointment of a second faculty member in the area in 1963 — Marvin Minsky, a researcher in artificial intelligence who worked with McCarthy at MIT — that would lead to the complete separation of mathematics and computer science.

As computer science's enrollments and research agenda continued growing in 1963, additional faculty slots were granted to the division. The university administration wanted to develop artificial intelligence at Stanford, seeing the possibility to strongly compete in the field against peer schools. Forsythe wrote in his budget request for the 1964-65 academic year that McCarthy was the strongest professor in the department and that he was transforming the division from "a modest mathematics-oriented group to a major role in computing."[22] McCarthy was in an excellent place to lead this movement because his research interests included both artificial intelligence and non-numerical computations. Forsythe argued that appointing Minsky to the division would complement this area by adding strength to McCarthy, as well as creating important connections to the Medical School.[23]

Joshua Lederberg, chair of the Genetics department, enthusiastically praised Minsky, writing that he was an "outstanding" choice for a position at Stanford. If appointed, Minsky would be given a joint professorship between Genetics and Mathematics, and Lederberg believed that Minsky could assist his department in

---

[22] Letter from Forsythe to Royden, 17 Dec. 1963, H&S Files, SC36/8/"CS: 64-65."
[23] Ibid.

its research in exobiology. Furthermore, Minsky would help with the "instrumentation crisis" facing biology and would develop new methods to combine the use of computers into the analytical equipment used in science and medicine. Furthermore, Lederberg placed the appointment into a grand narrative, connecting artificial intelligence with the search for a common paradigm in biology by comparing the adaptive processes of a computer to the evolution exhibited by cells. More strategically, Lederberg stated that the appointment of Minsky would allow Stanford to create a "concentration of talent" within artificial intelligence, allowing the university to become a national center, and asked the deans to dismiss "whatever controversy there may be concerning the actual present stature of this field of investigation."[24]

Lederberg was not a minor person at Stanford, and his advice was not easily dismissed. He had been awarded the Nobel prize just a few years before in 1958 at the age of 33, and Stanford attracted him that same year to found and chair the Genetics department. He was known among the faculty as an extraordinarily energetic researcher with wide intellectual interests. Given his intellectual heft, his words of praise for another scholar like Minsky would have held significant weight with the university administration.[25]

The praise for Minsky was not uniformly positive. Royden told Terman that

[24] Lederberg to Sears and Robert Alway, "Appointment of Dr. Marvin L. Minsky," 24 May 1963, H&S Files, SC36/89-114/8/"CS: 63-64."

[25] "The Joshua Lederberg Papers," Profiles in Science, National Library of Medicine, `http://profiles.nlm.nih.gov/BB/`

he had received letters from faculty that were pessimistic about Minsky and his research.[26] By June of 1963, Royden warned him that the nomination was "viewed with considerable skepticism" by senior administrators, since many of the letters argued that Minsky was smart but had not done much in the field.[27] By the end of the year, though, Royden would change his opinion of Minsky. That additional support was well-regarded by Terman, who wrote back to him that "your argument that you are sticking your neck out on this one with your mathematics colleagues makes a really strong point."[28]

The philosopher of science Patrick Suppes, who had been replaced as associate dean by Halsey Royden in 1962 and had returned to the Philosophy department, also wrote in favor of the appointment. He acknowledged that Minsky lacked the kind of publication record that would typically be expected for an incoming faculty member, but argued that the dean's office should support the candidacy since Minsky is "one of the few people of faculty status anywhere in the United States who is able to think creatively and originally about the non-routine problems of large computer systems."[29] Thus, Suppes argued that the definition of legitimacy should be expanded beyond just the typical evaluation of publications to include the potential of a candidate. Thinking strategically along the same lines as Leder-

[26]Unfortunately, Royden does not describe who wrote these letters.

[27]Royden to Terman, "Marvin Minsky," 6 Jun. 1963, H&S Files, SC36/89-114/8/"CS: 63-64."

[28]Terman to Royden, "Marvin Minsky," 3 Dec. 1963, H&S Files, SC36/8/"CS: 64-65."

[29]Suppes to Royden, "Appointment of Marvin Minsky," 7 Oct. 1963, H&S Files, SC36/89-114/8/"CS: 63-64."

berg, Suppes believed that Stanford could not become a national leader in the field relying exclusively on McCarthy, and thus an additional appointment was necessary.[30]

Suppes also told Royden to follow the divergence between mathematics and computer science as well as the nature of academic legitimacy. He wrote, “it is also important to realize that mathematicians [...] do not operate at the machine level.” Suppes contrasted the research of mathematicians, which “evaluates in standard fashion in the usual journal articles” with the research in computer systems that would be pursued by Minsky. Suppes wrote forcefully that “it is a hard but unpleasant fact as far as I'm concerned that the kind of original and creative thinking required to do imaginative things in computer systems is not the sort of thing that easily leads to publication, but that certainly is of an intellectual order comparable to research in many academic fields.”[31] Thus, we see a professor from the Philosophy department (and with strong interests in science) with administrative experience providing a strong argument for the legitimacy of artificial intelligence as a field of study.

Not surprisingly, Forsythe was very high in his praise of Minsky, but placed the appointment in the strategic framework of the division's growth. He wrote that Computer Science at Stanford had started around the research of numerical

[30]Ibid.
[31]Ibid.

analysis, but that the "the next area to be cultivated was Artificial Intelligence," which he defined as using computers to solve issues of pattern recognition, symbol manipulation and problem solving.[32] Research in the field "is a long-range endeavor, whose big pay-offs are distant but of fantastic importance," and thus Stanford should quickly take a leadership role. In terms of the department itself, Minsky would assist in bringing even more graduate students into the artificial intelligence area, and in Forsythe's judgment, Stanford would pull ahead of the current leading centers of Carnegie Tech and MIT with the appointment.[33]

Forsythe, however, did not completely deemphasize Minsky's mathematical connections. Minsky had his education in mathematics and was on the MIT mathematics faculty before moving into computation. Thus, Forsythe was sure that Minsky would "maintain high mathematical standards in Ph.D. theses written in the area of Artificial Intelligence."[34] Perhaps most interestingly, Forsythe argued that Minsky could help to heal the division between the numerical and non-numerical approaches to computer science that were beginning to split the division from the Mathematics department. Minsky would "foster an active collaboration between two groups in the Computer Science Division [the numerical analysts and the AI researchers] for the more intimate collaboration between computers and mathematicians in the solution of problems in analysis."[35]

[32]Forsythe to Sears, 11 Oct. 1963, H&S Files, SC36/89-114/8/"CS: 63-64."
[33]Ibid.
[34]Ibid.
[35]Ibid.

It was in mathematics, though, that the controversy over artificial intelligence would prove to be most acrimonious. Gilbarg recommended against the appointment of Minsky, arguing that he lacked a record of publications and was not necessarily a leader in the field. However, Gilbarg's objections were directed less at Minsky and more at artificial intelligence as a whole. Gilbarg argued that "perhaps no other scientific area represented in Humanities and Sciences is so full of talk of future possibilities and yet so lacking in actual accomplishments."[36] In Gilbarg's judgment, Stanford's appointment of Minsky would be highly risky because "Stanford would be gambling on the future of Artificial Intelligence as an academic discipline." He was deeply concerned that Stanford would appoint two fruitless faculty members, in a division that had only a handful of members.

More broadly, Gilbarg's primary concern was the direction of the division as a whole. By appointing Minsky, the division's focus would move away from numerical approaches to computer science and more toward non-numerical research. Considering that Forsythe was originally appointed to add numerical strength to the department, it was perhaps inevitable that there would be tension over the division's development. Gilbarg thought that the new direction would undermine the attempts to build up numerical analysis, and thus would weaken Stanford's first strong research area without developing a suitable replacement. Gilbarg con-

[36]Gilbarg to Sears, "Minsky appointment," 10 Oct. 1963, H&S Files, SC36/89-114/8/"CS: 63-64."

cluded, "I do question whether such appointments will in the long run make for a high quality department of Computer Science, and whether they are appropriate for the School of Humanities and Sciences."[37]

The collected comments of Lederberg, Royden, Forsythe and Gilbarg were provided to Robert Sears, a professor from the Psychology department who had responsibility for the appointment as dean of H&S. He was strongly enthusiastic of the appointment, believing that Stanford would not only build up artificial intelligence, but could develop a specialization in the computational aspects of biology and medicine. He sent Minsky's forms to the school's Appointments and Promotions committee, where the committee evaluated the conflict between Mathematics and Computer Science. The committee weighed the proposed appointment carefully, and concluded that it met the standards for a faculty position within the school.[38] The committee overruled Gilbarg's concerns by noting that he, unlike Forsythe and the other letter writers, was not in a position to judge the quality of much of his work.[39]

Sears himself added to the committee's dismissal of Gilbarg's objections, writing that "it is understandable" that he would want a numerical analyst who would benefit the department. However, Sears believed it best to allow the faculty of the division the autonomy to make their own decisions regarding hiring, provid-

[37]Ibid.

[38]Sears to Vennard, 19 Dec. 1963, Terman Papers, SC160/3/12/1.

[39]Sears to Terman, "Recommended Appointment of Marvin Minsky as Professor of Computer Sciences," 11 Nov. 1963, H&S Files, SC36/8/"CS: 64-65."

ing them more authority than was previously granted.[40] More importantly, Sears addressed the criticism that adding another faculty position in artificial intelligence was dangerous, given the relatively recent formation of the field Sears wrote that “I am fully aware that the whole enterprise of Computer Science represents a gamble on the part of the University.”[41] However, the difference between Sears and Gilbarg was that the dean was willing to foresee where artificial intelligence could lead: “In my opinion, the University must be prepared to make this kind of gamble every so often.”

Sears was aware that the gains in the field might not be realized for many years, but that it was important to lay the groundwork immediately. He wrote:

> I am convinced, however, that the imaginative application of brilliant intellection to the more effective use of computers will ultimately produce great dividends for many branches of science, and I feel a strong conviction that Universities have the responsibility to exploit every possible opportunity to stimulate and develop new fields of knowledge. Stanford made the decision four years ago to make one of its speculative enterprises the field of Computing Science. I think it is important that we back up this decision with the appointment of vigorous creative young faculty who can convert this speculation into a solid, producing,

[40]Ibid.
[41]Ibid.

blue chip enterprise.[42]

By the end of 1963, artificial intelligence had established a significant base of academic legitimacy within the administration, if not entirely among the faculty. It was this organizational flexibility that facilitated the rapid development of computer science at Stanford.

### 2.2.2 Ramifications

With the nearly unanimous support of the administration, an offer was made to Minsky, much to the chagrin of Gilbarg.[43] The consequences of the decision for the division of Computer Science were quick. Just a few weeks later, Gilbarg asked Sears in a brief memo to be removed from approving any new appointments within the Computer Science division, arguing that it would be "superfluous" given their growing size. He wrote briefly that the connections between the two fields were "at best tenuous" and that their research agendas were "diverging." Thus, it would be best for Computer Science to receive its own department removed from Mathematics.[44]

After some conversation, Sears approved the general sense of Gilbarg's goals, and informed Terman on how to implement it. He wrote that Computer Science

[42]Ibid.

[43]Minsky would later decline the offer, for reasons unclear, and remained at MIT for the entirety of his career.

[44]Gilbarg to Sears, "Computer Science Division," 2 Dec. 1963, Terman Papers, SC160/3/12/1.

will have two directions ahead for it, "one will be the quite elaborate 'how-to-do-it' teaching program" and the other will be "the non-mathematical research and graduate training."[45] Sears also acknowledged that the research in computer science, especially in artificial intelligence, was moving away from its origins within numerical analysis, and that "it is more in the nature of technology." Sears recommended the elimination of the Mathematics chair's review of new faculty positions, feeling that it would encourage the Computer Science faculty and "free them from what I sense they now feel as a kind of 'Big Brother' control."[46] Terman concurred with Sears, and felt that Computer Science was nearing department-level status within the university —perhaps in a year's time.[47]

Gilbarg may have been right on one level. Back in mid-1963, when he recommended against the appointment of Minsky, Gilbarg argued that another appointment outside of numerical analysis would likely increase the difficulty of making an appointment in that field. He was referencing the case of Seymour Parter, a mathematician and numerical analyst with strong interests in the growing field of computation. In his two previous positions at Indiana University and at Cornell, Parter had served in a joint appointment between mathematics and the campus computing center.[48] Considering the strength of Stanford in this field, he was a

[45] Sears to Terman, "Mathematics and Computer Science Division," 5 Dec. 1963, Terman Papers, SC160/3/12/1.

[46] Ibid.

[47] Terman to Sears, "Mathematics and Computer Science Division," 6 Dec. 1963, Terman Papers, SC160/3/12/1.

[48] "Biography of Seymour Parter," Feb. 1963, H&S Files, SC36/89-114/8/"CS: 62-63."

natural addition to the faculty, but Parter already had a full tenure offer to return to Indiana, putting pressure on Forsythe. He wrote to Gilbarg and Sears that people like Parter "come dear" and that the department should make an equivalent offer.[49]

The issues surrounding the appointment of Minsky would spill into the debate over Parter. The Mathematics department refused to offer him a joint appointment between Computer Science and Mathematics. Since the faculty of the division were members of the department, the difference was not one of budget but likely one of politics. Giving Parter a joint position would be acknowledging the authority of the Computer Science division to make its own appointments, and Gilbarg and many of the Mathematics faculty were likely opposed to setting such a precedent. Forsythe noted that Parter was "extremely sensitive" to the relationship between the two fields, and he would eventually turn down Stanford's offer to join the faculty.[50]

---

[49]Forsythe to Gilbarg and Sears, "Seymour Parter," 12 Mar. 1963, H&S Files, SC36/89-114/8/"CS: 63-64."

[50]Forsythe to Bowker, Gilbarg, Royden and Terman, "Seymour Parter declines," 12 July 1963, Terman Papers, SC160/3/12/1.

## 2.3 Computer Science and H&S

### 2.3.1 Building Connections and the Computation Center

As the Computer Science division grew out of the Mathematics department, it increasingly had to engage with the rest of the School of Humanities and Sciences to secure its faculty slots and to support its budget recommendations. Developing connections between Computer Science and other departments thus became crucial in the drive to develop the division into a full-fledged department. These connections were built most easily at the Computation Center, which was led by Forsythe from 1962-1965 and provided centralized computing resources for researchers across the university. However, there was a growing fear that Computer Science would be subsumed by other departments and relegated to an exclusively service role within the university.

As director of the center, Forsythe was a major proponent of computing's power to influence other disciplines, and he encouraged the use of the center's computers by maintaining an open access policy.[51] By autumn of 1963, the center was being used for sponsored research from several different departments and schools, including Physics, Electrical Engineering, Aerospace Engineering and the Graduate School of Business. The unsponsored usage, though, is more interesting. Several

[51] Essentially, no one was turned away from using the center, regardless of whether the work was sponsored or unsponsored.

social science departments, including Economics, Sociology, Political Science and Communications were using the computers as unsponsored users, as was Petroleum Engineering in the School of Earth Systems.[52] Thus, Forsythe's open access policy was having a significant impact on the spread of computation to disciplines outside of computer science and its immediate counterparts, since many of these departments had no sources of revenue to cover computing costs.

Beyond facilitating computing, Forsythe, as division head, actively sought to build connections with other departments. One example comes from late 1963, in which Forsythe worked with Marcia Ascher, a mathematician with interests in archaeology, on developing a computation class for archaeologists. Forsythe wanted the class to be accessible, even to those who did not feel comfortable in mathematics, writing that "Engineers, natural scientists, mathematicians, and anyone else who knows what a function is are to be barred at the door – so we can have a more cultural environment!"[53] This expansive use of computers and the need for computer science was noted by Forsythe in a report written shortly after the creation of the department in 1965: "It is now clear that students of social science must also acquire a familiarity with computing methods, And the serious student of humanities will soon find computers indispensable, if he is to carry out research on any substantial volume of data."[54] The same report also mentions that

[52] Computation Center to Hubert Heffner, "Incremental costs attributable to student computing," 5 Mar. 1964, Terman Papers SC160/3/12/2.

[53] Forsythe to Marcia Ascher, 18 Nov. 1963, Forsythe Papers, SC98/2/5.

[54] Forsythe, "Stanford University's Program in Computer Science," Technical Report CS26, 25

the department had arranged for one week sessions on computing taught directly to other faculty.

The connections between Computer Science and other departments also went the other way. In the early years, the Computer Science division could hardly teach a complete curriculum due to the small number of faculty in the program. Thus, a large part of the curriculum was taught by other departments, particularly the Mathematics department. At an educational panel discussion in 1965, Forsythe noted the importance of interdisciplinary activity when he noted, "Important Idea: CS is interdisciplinary. It's essential that our students learn supporting disciplines. I feel that control of curriculum is essential. That doesn't mean we should actually teach the entire curriculum."[55] This integration of other departments into the division's curriculum provided immediate legitimacy — no department will question the quality of its own classes.

Finally, the division developed its legitimacy through the creation of joint appointments with other academic units on campus. Stanford's provost, Frederick Terman, encouraged these joint appointments, including a critical one with the Stanford Linear Accelerator Center that would provide a billet for William F. Miller in the division.[56] Terman told Forsythe that these joint faculty members

---

Jun. 1965, ftp://reports.stanford.edu/pub/cstr/reports/cs/tr/65/26/CS-TR-65-26.pdf

[55]Forsythe notes, "Education Panel," 4 Sept. 1965, Forsythe Papers, SC98/2/50.

[56]Forsythe to SLAC File, 15 Jan. 1964, Terman Papers, SC160/3/12/2; Terman's support is noted in Forsythe, "Final Conversation with Bowker," 25 Sept. 1963, Forsythe Papers, SC98/2/17.

must serve the real needs of Computer Science, and he reminded him that Computer Science cannot be strong in all fields — a reference to his "steeples of excellence" approach to building academic departments. The need to maintain a strong leash on joint appointments became increasingly important toward the early 1970s when physicists increasingly left their field and sought work in computer science, many of whom were under-qualified for research.[57]

These academic connections from the Computation Center brought new ideas to the Computer Science faculty, but it led to on-going concerns about the development of computer science as a discipline. This concern was never far from the mind of Forsythe, who perceived that computer science had to create a coherent intellectual area with the requisite institutions to build legitimacy inside the academy. Forsythe pushed officers at the National Science Foundation to fund and develop a publication similar to *Mathematical Reviews* that would provide comprehensive coverage of new developments of computer science.[58] Later, he used the growing number of journals as indication of the rise of Computer Science as a discipline when requesting authorization to begin a PhD program.[59] The issue of legitimacy continued even after the creation of the department, and Forsythe argued that the main intellectual problem for Computer Science was expanding out while not

[57]For a history of the physics community, see Daniel Kevles, "The Physicists," Harvard University Press, 1995.

[58]Forsythe to Leland Haworth, 25 Nov. 1964, Forsythe Papers, SC98/15/2.

[59]Forsythe to Whitaker, "Ph.D. in Computer Science," 29 July 1964, Forsythe Papers, SC98/15/4.

becoming so diffuse that it dissolved into the individual departments.[60]

### 2.3.2 The Case of William F. Miller

The divide over the direction of Computer Science after 1963 and its role in the university came up in the tenure decision of William F. Miller, one of the original members of the Computer Science faculty who would later serve as Stanford's provost. Miller was a physicist, receiving his PhD in the field from Purdue in 1956 before joining the Argonne National Laboratory, working on the development of the computer. Given Miller's background in physics, he was nominated in 1964 to fill a joint faculty position between the Stanford Linear Accelerator Center (SLAC) and Computer Science. Such a joint position logically fit the interdisciplinary Miller, and also allowed the division to expand its faculty for just half of a salary.

His appointment was recommended by the division, and by the administration in the School of Humanities and Sciences. Despite this support, the case was not received well by the school's advisory Committee on Appointments and Promotions (A&P). There, the faculty voted unanimously against Miller's appointment. Given its advisory role, the committee's decision was not binding, and the School overruled and appointed Miller full professor of Computer Science later that year.[61]

---

[60] Forsythe, Abstract of Presentation to AAAS Berkeley, Dec. 1965, Forsythe Papers, SC98/14/24.

[61] Paul Flory to Dean Robert Sears, "Committee on Appointments and Promotions," 29 Jun. 1964, Terman Papers, SC160/3/12/2.

Chemist Paul Flory was a member of the A&P Committee at the time of the decision. He came to Stanford in 1961, already among the most eminent chemists in the United States. Previously on the faculty of Cornell University, he studied the physical chemistry of macromolecules, developing a theory for analyzing chain molecules quantitatively that would eventually lead to a Nobel Prize in Chemistry in 1974. Flory's stature was recognized at Stanford, where the administration placed him quickly on the A&P Committee.[62]

Flory was deeply concerned about the dean's decision to overrule the committee's decision on Miller. In a three-page letter, Flory explored not only the Miller case but also the wider issues of the role of professional and applied research at a place like Stanford. Regarding Miler, Flory wrote that he voted against him because of a lack of scholarly achievement. Commenting on speculation regarding the vote, he said that "The assertion that the Committee underestimated the significance of his contributions to computer science because of the unorthodox media of communication (ditto reports, etc.) in this field lacks credibility."

Given the state of the computer science field at the time, these kinds of reports, despite Flory's stature, may very well have been crucial scholarship, and we see the issue of legitimacy enter into the discussion. In addition, Flory was concerned that a candidate for the joint appointment would need "superhuman capacities"

[62] "Paul J. Flory - Autobiography," Nobelprize.org, 22 Jan. 2011, `http://nobelprize.org/nobel_prizes/chemistry/laureates/1974/flory-autobio.html`

since the job would entail so many different types of activities, and thus he was skeptical if any candidate existed who could fill the position.[63]

These concerns regarding scholarship were certainly not unusual in tenure discussions. However, Flory's arguments on the role of the professions deserves strong analysis. He began his letter by noting that he did not oppose Miller on the grounds that areas of applied science were moving too close to the School of Humanities and Sciences, even though "caution in this regard is imperative." While he argued that "scholarship should certainly take precedence over shades of distinction between the professional and the central disciplines," he continued, "the distinctions must nonetheless be regarded as significant in the academic scene."[64]

After the discussion of the Miller case, Flory unleashes his main argument against the direction that Stanford was taking: "In some way, appointments in 'growing edge enterprises' (my underline) are to be fostered with emphasis on areas of practical concern, because these latter are said to be the well springs of new disciplines. Accepted doctrine backed by a good deal of experience replete with familiar examples teaches the obverse, namely, that areas of practical import spring from advances in the disciplines."[65] He noted that his views are traditional and not keeping with the spirit of the times at Stanford. Flory then crescendoed

[63]Ibid.

[64]Ibid.

[65]Of course, this linear model of the progress of theory to applied science has been expanded by a wide range of scholars. See Stokes, Donald "Pasteur's Quadrant" for an encompassing discussion of these models

into his paramount argument:

> No university can hope to mirror all new and promising areas of technology with their manifold proliferations in the present age. In fact, it must constantly guard against the ever present temptation to try to do so in an age of specialization. There are also the closely related pressures to develop enterprises, and these can be lethal to a great university. It is no secret that many of the faculty are gravely concerned over recent tendencies in this direction. It would be a matter of great regret if the School of Humanities and Sciences were to abandon its position as the bulwark of the disciplines in order to take unto itself technologies and professions at what may momentarily appear to be "cutting edges" of "new frontiers."[66]

Flory's argument was the most articulated response to the rise of Computer Science at Stanford, and showed both the importance of legitimacy and the politics of knowledge in the development of computer science.

However, what makes his letter particularly notable is that Flory was not opposed to industrial research. On the contrary, he had conducted it himself. His first job after receiving his doctorate was at DuPont, and he later worked at the Standard Oil Development Company and the Goodyear Tire and Rubber

[66] Ibid.

Company during World War II. While Flory was most notable for his theoretical contributions in chemistry, he was not the quintessential academic scientist who avoided practical work. Computer science thus faced a more difficult battle for legitimacy than perhaps initially perceived. The faculty of the division did not just have to convince ivory tower academics, but also academics who had spent significant time in industry.

## 2.4 Conclusion

Despite Flory's criticisms, Computer Science continued to grow rapidly throughout 1964, and the university administration authorized it as a department on January 1, 1965. The discipline was very different from what Forsythe saw when he arrived in 1957. Numerical analysis was the exclusive province of the discipline then, but by 1965, the department included faculty engaged in areas as wide as physics and artificial intelligence. This development particularly worried Forsythe, who asked in mid-1965, "Has our creation of a new Ph.D. degree in computer science actually worsened the situation for the would-be numerical analyst?"[67]

Forsythe himself was fairly bitter about the entire situation ever since the conflict over the Minsky appointment. He had wanted a joint appointment with

[67] Forsythe, "Stanford University's Program in Computer Science," Technical Report CS26, 25 Jun. 1965, `ftp://reports.stanford.edu/pub/cstr/reports/cs/tr/65/26/CS-TR-65-26.pdf`

Mathematics when the Computer Science department was formed, but the request was denied. In addition to the lost benefits of communication, Forsythe was frustrated about the work he had put into Mathematics since arriving at Stanford in 1957, especially guiding six or seven PhD dissertations in Mathematics.[68]

The politics of knowledge at the heart of the debates over Minsky and Miller provide a rich window to develop a framework to analyze the formation of disciplines. Academic legitimacy may often need to be redefined in new fields, and this can lead to particularly difficult challenges in developing support among the members of other disciplines, which are already established and viewed as legitimate. In the Stanford case of Computer Science, the discipline benefitted from strong university administration support that helped to create the conditions that increased its legitimacy within the university, and it is here that we turn to next.

[68]Forsythe to Royden File, "Conference 22 Jan. 1965," 25 Jan. 1965, Forsythe Papers, SC98/15/1.

# Chapter 3

# The Computer Science Department and Entrepreneurial Culture

Computer science researchers across the nation faced the difficult task of building up programs without the academic legitimacy afforded to traditional disciplines in the university. Computation and its related science at universities in the United States typically developed as applications of other disciplines, particularly physics.[1] There was thus an immediate question whether computer science was itself a discipline, or merely a component of other fields.

Establishing academic legitimacy was typically even more difficult because computation and computer science were really composed of two separate groups of activities. On the service side, there was the provision of computing resources to other departments and research centers at the university. At campus computation facilities, programmers would assist professors in writing programs for use in the computer — acting as office staff as opposed to faculty. On the academic side, however, there was the investigation and pursuit of fundamental knowledge of how computers worked as well as the theoretical mathematics that underpinned their operation. There was generally incredible tension between these two sides, and as Atsushi Akera has shown, they "disintegrated" at MIT and the University of Michigan.[2]

The story at Stanford was radically different. Computer science grew out of the interests of two professors of numerical analysis, George Forsythe and John

[1]For a survey at the beginning of the 1960s, see Louis Fein, "The Role of the University in Computers, Data Processing, and Related Fields," Communications of the ACM, Vol. 2, No. 9 (Sept. 1959), pg. 7-14.

[2]Atsushi Akera, Calculating a Natural World, MIT Press, 2008.

Herriot, who believed that computation would reshape the field of mathematics. From the beginning, they developed a program with heavy emphasis on theory. For example, the courses when the department was founded in 1965 included only a handful of applications-based courses such as "Computer Simulation of Cognitive Processes" and arguably "Data Reduction and Control Programming." Other courses focused on introductory programming skills, numerical analysis, formal languages, artificial intelligence, and digital systems.[3]

Furthermore, the disintegration of the service and academic wings of computer science never occurred at Stanford. Quite the opposite, Stanford's Computation Center would actively facilitate the development of the Computer Science division, and after 1965, the Computer Science department. There was tension between the two organizations over the center's financial subsidization of the department, particularly in the later years of the 1960s when revenues became more difficult to secure. However, the Computation Center continued to provide 17% of the the Computer Science department's budget in 1970, and many personnel held joint appointments between the two organizations.[4]

Why is the story of computer science so different at Stanford? This chapter answers this question by exploring the institutional factors that led to the rise of

[3]Courses may have had applications of theories, but the main intention of the vast majority of courses in the department was clearly the teaching of theory. Forsythe to File, "Meeting 5 January 1965,' 19 Jan. 1965, Forsythe Papers, SC98/15/1.

[4]Forsythe to Sears file, "Conference of 12 Nov. 1969," 13 Nov. 1969, Forsythe Papers, SC98/14/7.

the Computer Science department, including its success in expanding the Computer Science faculty as well as building academic legitimacy within the university. It provides a primarily historical institutional lens of the expansion of the department, analyzing the people and organizations that shaped its rise. However, it also evaluates the culture of both the department and the university administration as a critical element that assisted in the department's success.

This chapter looks at four intersecting institutional factors and patterns that were crucial for the success of the department. First, a warm and productive relationship characterized the connections between the Computation Center and Computer Science throughout most of the 1960s. Forsythe headed both groups in the early years of 1962-1965, building a culture of openness and collaboration between the center and the division that continued even after he left the Computation Center to chair the newly formed Computer Science department.

Within the department, Forsythe was aggressive in offering new courses and expanding student enrollment, a second important factor in the development of the department. When Forsythe arrived in 1957 at Stanford, there was barely a notion of computer science, and certainly no academic courses in the field. Within a little more than a decade, the Computer Science department had enrollments at the undergraduate and graduate level of more than 2,500 students combined per academic year.[5]

[5]Forsythe to Computer Science Advisory Committee, "Report on Computer Science Depart-

The need to expand student enrollments and the leadership of Forsythe helped to inculcate a culture of entrepreneurship among the Computer Science department's faculty that is reminiscent of today's start-up companies in Silicon Valley. The department had strong and confident leadership, an ability to boot-strap new programs and classes on limited budgets, a disregard of bureaucratic constraints (much to the exasperation of senior university leaders), and fundamentally, an expansive vision for the field of computer science. Taken on a holistic level, Forsythe's papers show a leader who was supremely confident in the importance of his discipline, and took advantage of every opportunity to push the university administration for additional funds. He was simultaneously forceful, energetic, and cleverly spirited in his pursuit of building the field.

Despite his administrative talents, Forsythe was not an intellectual heavyweight when he arrived at Stanford, unlike some of the faculty that opposed his expansion plans as seen in the last chapter. However, despite the stature of the opposition arrayed against him, the university administration continued to support the development of the Computer Science department, matching the growth of students with new funds remarkably well over the course of the 1960s. This chapter will argue that a third factor important to the Stanford case was a culture among university administrators of organizational flexibility and passive facilitation toward computer science, partly due to their own educational and academic backgrounds.

ment," 19 Oct. 1970, Forsythe Papers, SC98/1/19

University provost Frederick Terman would play a crucial role in providing some of the initial funding of the department as well as in providing advice from his own experience in developing the Electrical Engineering department. The various deans of the School of Humanities and Sciences, who had direct budget authority for Computer Science,were generally supportive if not always leading champions of the department. This passive facilitation is apparent in numerous examples in which Forsythe would add classes or make commitments to spending without prior approval from the school. The school would find the funds to meet the obligation, admonishing Forsythe to avoid the problems in the future without truly seeking to change his ways. Thus, the school accommodated Forsythe's ambitious expansion strategy, while never actively endorsing the goal itself.

The fourth and final factor that assisted the department's rise is rather counterintuitive. The focus of the faculty on theory and their desire for academic legitimacy encouraged a strong focus on building up the department's doctoral program at the expense of undergraduates and industry students. In fact, it would be decades before the department would offer an undergraduate major. However, the department ended the 1960s with thousands of dollars of annual revenue from industry developed through joint university-industry programs, and it would expand its course offerings at the undergraduate level, teaching a record number of undergraduates in one year. Why did the department change?

A combination of negative financial trends, including a growing deficit at the Computation Center, nationwide inflation, cuts to defense research agencies due to the Vietnam War, and declines in endowment funds, forced the department to seek new sources of revenue to sustain its operations and expansion plans. Dissenting from the typical interpretation of university financing, this chapter argues that it was actually the *lack* of funds, both for its budget and for a new academic building, that forced the Computer Science department to engage with industry and create the regional innovation networks that would create Stanford's "steeple of excellence" in computer science.

## 3.1 The Computation Center

The Computation Center was the primary means of receiving computing at Stanford University. As such, it played a crucial role for researchers and students who were conducting computer research. However, its role also expanded to subsidize the Computer Science department, both directly and indirectly. The close relationship between the two organizations —the service wing with the center, and the academic wing with the department —facilitated this subsidization despite increasing concerns from the university administration about the benefits of the arrangement. Given the department's tight budget within H&S, the center provided a crucial financial lifeline, while also serving as a venue for engaging other academic departments.

The development of the Computation Center and the Computer Science division in the early 1960s was facilitated by Forsythe, who served as the head of each. He effectively, if unofficially, merged the accounts of the two organization, financing people from whatever budget currently had funds. This particularly annoyed the meticulous Terman, who complained in late 1963 that "funds for running the Computation Center, and budget accounts of the Division of Computer Science should not be regarded as interchangeable."[6] The center's subsidization included not just funds for faculty (many of whom were jointly appointed between the division and the center), but for graduate students as well. In 1964, 10 graduate students received their stipends from the center's general funds.[7]

Financing the Computation Center in these years became increasingly difficult because of a lack of revenues. Due to the novelty of the technology, funding agencies and the university were not entirely accounting for the costs of computing time. In the 1962-1963 academic year, the center received revenues for slightly more than half of the utilization of the center. Unsponsored research, essentially time donated to faculty and students,accounted for 26% of the total computation time in the center, with the remaining 22% of the time being used for class

[6]Terman to Royden, "Computer Sciences," 8 Nov. 1963, Terman Papers, SC160/3/12/"CS and Center: 62-63."

[7]Forsythe to Virgil Whitaker, "Graduate Aid Available and Desirable," 16 July, 1964, Sterling Papers, SC216/1/1/26.

assignments.[8] The latter two were effectively subsidies to the Computer Science division's research and education program. By 1967, the direct subsidy for the department represented approximately 21% of the department's budget for faculty —almost equal in size to external research grants.[9] The budget pressure created by these subsidies started to affect the number of graduate students the center funded, with some of the slots eliminated in order for the center to purchase new equipment.[10] Furthermore, there was increasing faculty dissent about the queueing system at the center, which gave no priority to funded versus unfunded computing tasks. That dissent encouraged the creation of a Committee on Computing that would develop policies for creating a prioritization system for running jobs at the center.[11]

Much as with the Computer Science department, the center's unstable revenues encouraged a "start-up mentality" to secure new sources of funding. Forsythe would later remove himself from directing the Computation Center with the formation of the department in 1965. The center continued its rapid expansion, eventually reaching $1,500,000 in operating expenses in 1967, with plans to increase to $2,500,000 by 1970. The same report cautioned that "expenses are extremely high, and income is never certain," and thus the center is continually "on the

[8] "Computation Center," Sterling Papers, SC216/1/1.5/27.

[9] "The Future of Computer Science at Stanford," 8 Feb. 1967, Lederberg Papers, SC186/10/4

[10] Forsythe to Virgil Whitaker, "Graduate Aid Available and Desirable," 16 July, 1964, Sterling Papers, SC216/1/1/26

[11] Forsythe to Bowker, "Request for more parting advice!," 6 Sept. 1963, Forsythe Papers, SC98/2/19.

edge of bankruptcy." If the center suddenly experienced a drop in revenues, the fear among the faculty was that it "could force drastic retrenchments in the entire university."[12] In response, the center began reaching out to other parts of the university and to external organizations that might find computing useful. Some examples include local law enforcement (for crime statistics), Stanford's law school (for joint degrees on privacy and statistical studies of the legal practice) and special training programs for minorities.[13] Even though the funding was precarious, the Computation Center continued to subsidize the Computer Science department to the tune of $107,059 in 1967, only slightly behind H&S in funding, which stood in the 1967-68 academic year at $133,000.[14] Thus, the fate of the two continued to be intertwined throughout the decade.

While subsidization of the department continued, the worries about revenues were justified just a few years later when nearly all academic units at Stanford were hit with budget cuts. Various funds began running out, including a grant from the National Science Foundation and the Provost's Computing Funds (which until then had attempted to cover some of the unsubsidized research expenses at the center). By 1970, the center was facing a deficit of a half million dollars, and in 1972, the deficit was likely to double to one million dollars.[15] The university responded by

[12]"The Future of Computer Science at Stanford," 8 Feb. 1967, Lederberg Papers, SC186/10/4.

[13]John Ehrman to Susan Kolasa, "Ideas for Funded Programs in SCC," 23 Sept. 1971, Forsythe Papers, SC98/2/38a.

[14]Feigenbaum to Ron Jamtgaard, "Approximate Annual Subsidy of CSD by SCC," 17 Nov. 1967, Miller Papers, SC208/3/1.

[15]E. Howard Brooks to Budget Files, "Budget Conference with Associate Provost W.F. Miller,"

raising user fees and cutting some unsponsored research work, but staff members felt that the center's administration were "contemplating their navels" in solving the budget crisis.[16] These financial pressures forced the center to aggressively reduce its subsidy for the Computer Science department. In 1970, this subsidy was reduced to $28,000, out of a budget of $165,000 (or roughly 17% of the budget).[17] Forsythe described the loss of personnel support from the center in 1970 as "a natural consequence of the Computation Center's tight finances and consequent need to cease furnishing unreimbursed services to our Department."[18]

The Computation Center actively worked to subsidize the programs of the Computer Science department, both directly and indirectly. Forsythe and the later directors of the center used it to build up computing at Stanford, with little regard for the finances of how the whole enterprise might work out. For its part, the university administration took a relatively hands-off approach to the subsidies, despite the increasing risk of a budget deficit at the center. These subsidies made the department's budget easier to handle for H&S, and thus there was an incentive to ignore the subsidy despite its cost to the users of the center.

6 Jan. 1969, Lyman Papers, SC215/1/"Comp. Center 1964-1969."

[16]Paul Armer, "Brief Overview of the Stanford Computation Center," 12 Mar. 1970, Lederberg Papers, SC186/4/1.

[17]Forsythe to Sears file, "Conference of 12 Nov. 1969," 13 Nov. 1969, Forsythe Papers, SC98/14/7.

[18]Forsythe to Computer Science Advisory Committee, "Report on Computer Science Department," 19 Oct. 1970, Forsythe Papers, SC98/1/19.

## 3.2 Building a Budget and an Entrepreneurial Culture

An introduction to university budgeting is critical to understanding the department's desire to expand course enrollments. The main revenue streams for Stanford in the 1960s were tuition, research grants, endowment income, and auxiliary revenue (including industry grants and other sources of income). Tuition was the most flexible source of funding, and as such it was often the first source for new initiatives at the university. Research grants were normally given by the federal government and foundations for specific proposals, and are rarely convertible to other university needs.[19] However, most of them do include some notion of "overhead" or discretionary revenue that can provide the university some budgetary flexibility. Endowments were provided by donors and were usually constrained in scope when given, making them flexible within a given domain but not flexible across the university. Finally, auxiliary income often stayed with the source of revenue (for example, revenue from clinical treatments generally stays with the medical school).

Thus, the primary issue facing the Computer Science department was finding fungible funds. Competition for these funds is typically fierce between all academic

[19] At the time, defense research grants were relatively more undirected than similar grants today.

departments, and computer science's lack of stature should have proven difficult to overcome. However, academic legitimacy is not the primary criterion for receiving funds from the university. Instead, course enrollments often drive the year-to-year changes in budgeting. Increasing course enrollments in a department will generally encourage the university administration to invest new resources in that area. It is this relationship that Computer Science hoped to exploit as part of a multi-pronged strategy to secure more funding.

One method used to receive more funds was simply to spend more. Forsythe disdained the budget restrictions placed on the department, and regularly misspent the money and spent more than allowed as he believed best fit the goals of the discipline. In the early years when Forsythe was head of the Computation Center and head of the division of Computer Science, he appeared to spend from both accounts freely, ignoring the university's bureaucracy and budget processes.[20] Another example came two years later when the department forgot to request funds for the salary of its department secretary in its budget request, asking the university administration for additional funding to cover her. Royden would move money from one of the department's industry funds, writing to Terman that the move "may cause the Department to be a little more careful about budgeting in the future, but this is probably wishful thinking on my part."[21]

[20]The issue was part of the concern seen in the last chapter over separating the Mathematics and Computer Science budgets. Terman to Royden, "Computer Sciences," 8 Nov. 1963, Terman Papers, SC160/3/12/"CS and Center: 62-63."

[21]Royden to Terman, "Missing salary for Diana Saunders," 21 June 1965, Terman Papers,

As the Computer Science division developed, so did the demand from students for classes. Much to the exasperation of senior Stanford administrators, Forsythe and other Computer Science faculty continually allowed greater numbers of students to take their classes and often offered more sections than were budgeted. Halsey Royden, an associate dean of H&S, wrote to Terman that the school had not given approval for extra sections for one course, but had "slipped up" in watching the number of sections that the division had created.[22]

Forsythe's enthusiasm to have Computer Science teach more students assisted the department's claim for more money. The 1960s were a time of expansion at Stanford, and the School of Humanities and Sciences was no exception. However, the breakdown of this increased funding was constantly debated. These teaching funds were essentially zero-sum: gains made in the Computer Science division would have to come at the expense of the growth of other departments. Developing high enrollment numbers was thus a useful strategy for the division, giving Forsythe a cudgel to use in budget negotiations against other departments. The large enrollments and small size of the faculty also meant that class sizes were necessarily quite large, and this helped in the yearly budget negotiations.

Using this marginal analysis, Forsythe continually believed that computer science was underfunded by the university, and demanded more funding in the years

SC160/3/12/2.

[22]Royden to Terman, "Facts about Computer Science," 17 Oct. 1963, Terman Papers, SC160/3/12/1.

following the 1965 creation of the department. This notion of finances fit into the philosophy developed by provost Frederick Terman, who told Forsythe that "Dollars will be scarce in coming years. It will be essential to accomplish a lot with a little money."[23] Taking the lead, Forsythe argued in 1970 that the department was underfunded by $65,000 to $200,000 a year in teaching funds. He compared Stanford's budget numbers with those for Computer Science at Cornell, which received roughly double the amount of funds while teaching fewer students.[24] The issue would continue into the 1970s, with a 1975 report noting with deep concern that the Computer Science faculty had a sense of "inadequate university support," and it also observed that none of the new 75 chairs in the school were assigned to the department[25]

Throughout the 1960s, there was a growing fear that other departments at Stanford might try to teach classes in computation, particularly given the large enrollments students experienced in computer science courses. Despite the inherent interdisciplinary nature of the field, the department was mostly successful in maintaining centralized control of the teaching of computer science within the university. One of the major concerns with this development was that students would lack a coherent understanding of the new field. In response to a question

[23]Forsythe to Terman file, "Fred Terman on computing plans," 29 Apr. 1969, Forsythe Papers, SC98/14/9.

[24]Forsythe to Raymond F. Bacchetti, "Request for study of instructional costs and class sizes," 27 May 1970, Lyman papers, SC215/1/"CS68-71."

[25]"Report of 1975 President's Advisory Committee on Computer Science," Feigenbaum Papers, SC340/13/23.

of allowing other departments to teach introductory courses, Forsythe wrote that "If we left the introductory course to the user departments, I think the students would fail to see computing as a changing subject, much in need of development by the students themselves."[26] Forsythe saw the students as potentially the next generation of computer scientists, and he viewed introductory classes as the means to proselytize the new discipline.

While educational concerns were certainly one element of the fear, financial concerns were at the heart of the Computer Science faculty's concerns. In a report generated in 1967 on the future development of the department, the department's faculty noted that they felt threatened by the rise of computer-based classes in other academic fields in mostly financial terms. "Given relatively unlimited funding, we would have no objection to parallel and even competing projects in our field," but this was obviously not the case, and they complained to the university administration that "it seems quite unjust to see funds and space made available for computer science in other parts of the university," when its academic home was so poorly funded. They also made it clear that only the Computer Science department should have the sole authority to appoint computer scientists at Stanford.[27] These views were later summarized by John McCarthy, the artificial intelligence researcher, who wanted to ensure that the department would "monop-

[26]Letter from Forsythe to Daniel Bailey, 19 Nov. 1965, Forsythe Papers, SC98/3/7.
[27]"The Future of Computer Science at Stanford," 8 Feb. 1967, Lederberg Papers, SC186/10/4.

olize" computation at Stanford —an ironic choice of words given the later nature of the computer industry.[28] The lack of funds for the department encouraged more centralization of the computing curriculum than might be expected for such an interdisciplinary field.

Underlying these trends of centralization was a belief that computation at Stanford would be intrinsic to the university in just a few years, and that the university was uniquely positioned to take leadership of the field. Forsythe believed that computer science would become one of the most popular fields in the university, and he envisioned a department that might even reach 100 faculty members to handle the growth in demand.[29] For the faculty at the time, there was already recognition of the differences between Stanford and its peer departments. Forsythe believed that Stanford had succeeded well with limited funding, but acknowledged the immediate advantage of better-funded peer departments. "Contrast Michigan, with a big infusion of Ford money in the engineering computing line, MIT, with project MAC costing ARPA millions of dollars, or Carnegie Tech, with Mellon money, or Cornell, with recent Sloan money. Hence Stanford is a very fruitful place to plant some big bucks."[30] Despite such funding, Terman believed that other universities handled their finances in computer science poorly, and thus "a reasonable amount of work

[28]Forsythe to Senior Faculty File, "Meeting of 18 March 1968," 18 Mar. 1968, Forsythe Papers, SC98/14/15.

[29]Forsythe's number would place Computer Science as almost a quarter of the faculty of the school. Forysthe to Reddy, "Computer science in the future," 1 May 1968, Forsythe Papers, SC98/14/13.

[30]Forsythe to File, 4 Mar. 1966, Forsythe Papers, SC98/14/20.

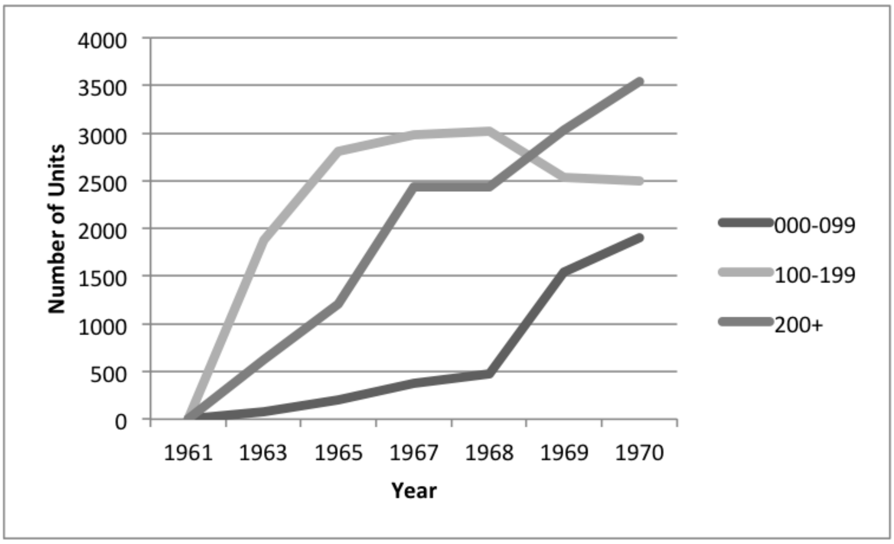


Figure 3.1: CS-taught Units for the 1960s

will pay off very well."[31] This optimism played a crucial role in the approach that the Computer Science faculty took in expanding the department.

However, there were disadvantages to the the growth of student enrollments and the department's teaching budget. Figure 4.1 shows the growth in the number of units taught over the course of the decade.[32] It is important to note that the 200-level courses, which were graduate level but accessible to undergraduates, had greater than linear growth throughout this period. 100-level classes, which are most typically designed for undergraduates, grew quickly before the creation of the department in 1965, but remained steady afterward. The late growth of the 000-level classes was due to the creation of introductory classes in the department,

[31]Forsythe to Terman file, "Fred Terman on computing plans," 29 Apr. 1969, Forsythe Papers, SC98/14/9.

[32]Date comes from Academic Planning Office data. "APO Data for Years 1959-1970," 19 Oct. 1970, Forsythe Papers, SC98/1/19.

which greatly expanded the number of students who could study Computer Science. All of these courses were not created equal: some cost as little as $5 per unit and others as much $170 per unit, depending on the extent of programming assigned in the course.[33] This full coverage of computer science may have forced the teaching budget higher, but it placed greater demands on the faculty than for professors at peer departments, and Forsythe observed that this "really hurts" the competitiveness of the department.[34]

University budgeting is generally characterized by its slow year-to-year change. Throughout the 1960s, Computer Science at Stanford faced the problem of securing money in its teaching budget commensurate with the growing numbers of students in the field it served. Figure 4.2 shows the growth of the CS budget over the 1960s, and Figure 4.3 shows the growth in the number of students enrolled in at least one class over the same time period.[35] The number of students, both undergraduate and graduate, increased at a rapid pace throughout the decade —almost doubling every two years.[36] However, the university managed to expand Computer Science's teaching budget roughly commensurately with the growth in student numbers: both student enrollments and the budget grew by about five times from 1961 to

[33]Forsythe to Sears and Moses File, "Conference 14 Apr. 1966," 15 Apr. 1966, H&S Papers, SC36/8/"CS 65-66."

[34]Forsythe to File, 4 Mar. 1966, Forsythe Papers, SC98/14/20.

[35]A contract was an external funding grant provided to the department. The data for both charts comes from Forsythe to Computer Science Advisory Committee, "Report on Computer Science Department," 19 Oct. 1970, Forsythe Papers, SC98/1/19.

[36]Forsythe to Sears and Moses File, "Conference 14 Apr. 1966," 15 Apr. 1966, H&S Papers, SC36/8/"CS 65-66."

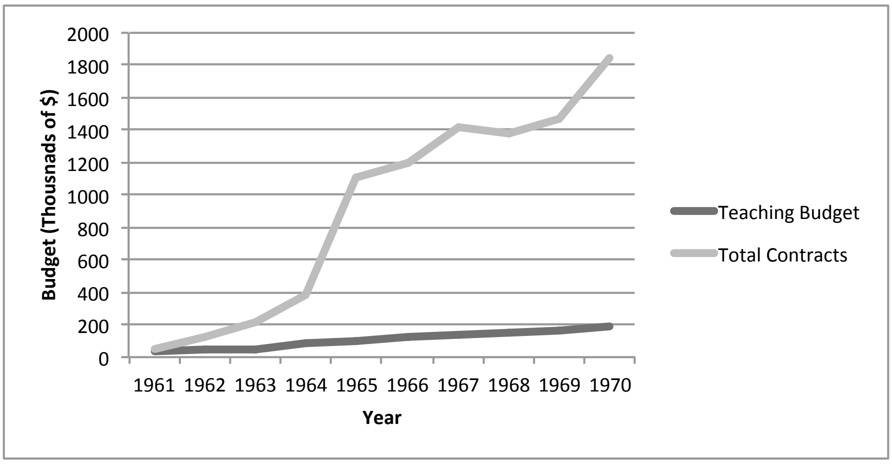


Figure 3.2: CS Budget for the 1960s

1970.

In summarizing the Computer Science department's growth strategy, the old adage of "if you build it, they will come" would seem to apply. Its faculty aggressively expanded the number of courses offered, and students swarmed the department's offerings. The increasing visibility of the department forced the university administration to budget more teaching funds to computer science. In a way, the department was setting the financial agenda of the school, and it is this sort of passive facilitation of the growth of the department that proved critical for its success.

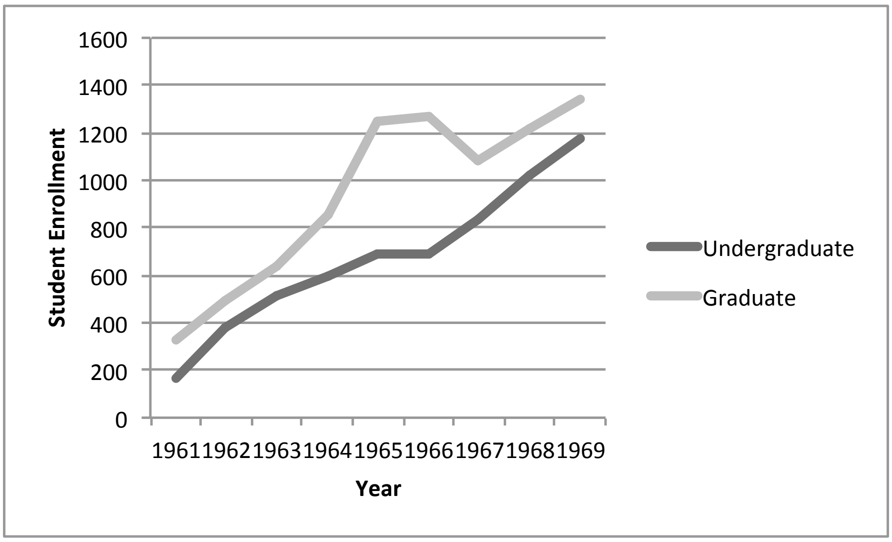


Figure 3.3: CS Enrollments for the 1960s

## 3.3 Support of the Administration

The Computer Science department benefited from university administrators who varied in their support and acquiescence in handling the financial growth of the department. Despite the vigorous protests of some faculty in the natural sciences, as explored in the last chapter, there was remarkably positive support among the administration for the growth of the field throughout the 1960s, a strong benefit for a nascent discipline with little academic stature. University provost Frederick Terman proved instrumental in ensuring the health of the Computer Science division's budget before 1965, and later helped the Computer Science faculty develop the department's approach to industry. Toward the end of the decade, during the tough financial years of the Vietnam era, Computer Science would become the sole department in the university to continue expanding amid budget cuts.

The backgrounds of Stanford's administrators proved quite beneficial for the department. Terman earned a ScD in Electrical Engineering from MIT under the direction of Vannevar Bush, who became the "father" of the National Science Foundation and led the policy development of the government's approach to financing science.[37] The two kept in contact throughout the years, and Terman used his access to Bush to receive advice on securing grants for Stanford. Bush was an early and strong supporter of computing, and it is quite probable that Bush's support encouraged that of Terman as well.[38]

Another administrator was Halsey Royden, who served as an associate dean, acting dean and later dean of H&S. He was a professor and former chair of mathematics, but did not join his colleagues in their dissent to the Computer Science department's growth. Royden's interests were in complex analysis, particularly Riemann surfaces, but he also held a strong interest in undergraduate education, leading the Mathematics department's overhaul of its major in the 1950s. Perhaps most importantly for this study, Royden started at Stanford as a member of the Applied Mathematics and Statistical Laboratory, a research center with important connections to computation.[39]

---

[37]C. Stewart. Gillmor, Fred Terman at Stanford, Stanford University Press, 2004.

[38]G. Pascal. Zachary, Endless Frontier: Vannevar Bush, engineer of the American Century, The Free Press, 1997.

[39]Brad Osgood, Ralph Cohen and Albert Hastorf, "Memorial Resolution: Halsey Royden." 1993, `http://histsoc.stanford.edu/pdfmem/RoydenH.pdf`

That background was similar to the dean of the Graduate Division, Albert H. Bowker, a professor of Mathematics and Statistics and founding chair of the Statistics department throughout the 1950s. He worked in the same laboratory as Royden, and Bowker was interested in applying mathematical statistics to issues related to engineering. He would go on to a substantial administrative career after Stanford, becoming chancellor of the City University of New York and University of California – Berkeley.[40]

The dean of H&S in the early years, Robert Sears, was a notable child psychologist who expanded the research on IQ tests —an area pioneered by Lewis Terman, father of Frederick Terman. Sears continued Lewis Terman's long-range study of children with high IQs, publishing several significant studies. While his research did not connect to computation directly, his personal connection to Frederick Terman likely influenced his deference to handling computer science.[41]

It was Terman, undoubtedly, who proved the most influential and supportive of Computer Science among these senior administrators, especially in the years before 1965. He quickly recognized the value of the new field, and Forsythe felt that the provost understood the situation faced by Computer Science as early as 1963.[42] Later that year, Terman began supplying his own discretionary funds to

[40] "A.H. Bowker's Home Page," `http://stat-www.berkeley.edu/users/bowker/`

[41] Alfonso A. Narvaez, "Dr. Robert R. Sears, 80, Is Dead; Child Pyschologist and Educator." The New York Times, 26 May 1989, `http://www.nytimes.com/1989/05/26/obituaries/dr-robert-r-sears-80-is-dead-child-pyschologist-and-educator.html`

[42] Forsythe to Files, "Final Conversation with Bowker," 25 Sept. 1963, Forsythe Papers, SC98/2/17.

the division, because he believed that the division was underfunded.[43] The budget transfer eventually reached $5,000 a year, enough to appoint an additional joint faculty member to the division.[44] Terman wanted the division to quickly grow and reach department status, and he thought that early funding would greatly assist the effort. Terman's timeline was ambitious. Concurrently with the formation of the division, Terman remarked that department status was likely only a year away provided everything continued to go well.[45]

Terman's desire to move quickly on computer science was likely colored by his own experience expanding the Electrical Engineering department at Stanford. There, he greatly increased the academic calibre of the department by securing greater government funding and industrial revenues.[46] Terman called the idea of building strong academic departments "steeples of excellence." In the case of electrical engineering in the postwar years, Terman had to build up an academic program against strong competitors who were already well-established, such as MIT. In the case of computer science though, there were no established departments, and Terman likely saw an opportunity for Stanford to easily build a steeple of excellence in the discipline if it was willing to move resources. His approach in the university was later adopted by the Computer Science faculty in positioning

[43]Forsythe to Files, "Conference with Bowker," 3 Dec. 1963, Forsythe Papers, SC98/2/17.

[44]Terman to Royden, "Computer Sciences," 8 Nov. 1963, Terman Papers, SC160/3/12/"CS and Center: 62-63,"

[45]Terman to Sears, "Mathematics and Computer Science Division," 6 Dec. 1963, Terman Papers, SC160/3/12/1.

[46]C. Stewart. Gillmor, Fred Terman at Stanford, Stanford University Press, 2004.

their own department—they argued that the university should unevenly supply additional funds to "selected areas" that the university felt worthy of expansion.[47] Later, Terman advised the senior leadership of the department on how to create a strong program, urging them to build "steeples of excellence that are in the mainstream of the future development of the subject. You don't need many steeples, but they should be high."[48]

In addition to Terman, the Computer Science division benefitted from the strong encouragement and passive facilitation of its most immediate administrators. The associate dean Halsey Royden supported the division in its relationship with other parts of the university, and he was generally enthusiastic about expanding the division's budget. During the conflict with the Mathematics department over the appointment of Marvin Minsky (see last chapter), Royden lobbied for the appointment behind the scenes with Terman, who appreciated that Royden was "[...] sticking your neck out on this one with your mathematics colleagues [...]."[49] In late 1963, Royden also supported providing the new division with more discretionary funds, and he lobbied Terman to provide them from provost's funds, arguing that the division needed more "hard money" to be able to hire additional faculty members.[50] Terman did give the funds just a few months later.

[47]"The Future of Computer Science at Stanford," 8 Feb. 1967, Lederberg Papers, SC186/10/4.

[48]Forsythe to Terman file, "Fred Terman on computing plans," 29 Apr. 1969, Forsythe Papers, SC98/14/9.

[49]Terman to Royden, "Marvin Minsky," 3 Dec. 1963, H&S Files, SC36/8/"CS1964-65."

[50]Royden to Terman, "Computer Science Division," 7 Oct. 1963, Terman Papers, SC160/3/12/1.

In the years after 1965, Computer Science benefited from significant donations from corporate sponsors that removed much of the pressure on Stanford administrators to find funding from university sources. However, even the new funding did not smooth the difficulty of the funding picture in the late 1960s. A combination of factors, including high inflation, decreasing endowment returns, and a murky government funding picture due to protests over the war in Vietnam, brought tremendous pressure on universities across the United States, and Stanford was no exception. The president of the university wanted to make base budget cuts in the 1970-1971 academic year, and instituted a hiring freeze throughout the university.[51] However, the constant prodding of Forsythe and the relatively enthusiastic support of university administrators allowed the department to thrive even in this inauspicious fiscal climate. By 1974, the H&S School recognized that the Computer Science department was underfunded, and Computer Science became the only department that year that did not have to plan for an actual budget reduction.[52]

Together, we see that the cultures of the department and the administration complemented each other surprisingly well. Despite the displeasure of administrators, Stanford did have the funding necessary to finance computer science's growth, and Forsythe never stopped demanding, and continuing to secure, a greater share

[51]Forsythe to Sears file, "Conference of 12 Nov. 1969," 13 Nov. 1969, Forsythe Papers, SC98/14/7.

[52]Floyd to CSD Faculty, 18 Dec. 1974, Forsythe Papers, SC186/5/2.

of resources. Stricter university governance over budgeting and finance would have almost certainly retarded the growth of the department. Likewise, a less bold and more timid leader of the Computer Science department would not have sought out the opportunities and gambled so many times to push the discipline forward.

## 3.4 Developing New Venues

A perennial problem facing the Computer Science division and later the Computer Science department was a lack of physical space. Budgeting in university environments may be slow, but physical space growth can be nearly glacial. It would take more than a decade before the Computer Science department would receive a dedicated building, and before this construction finished, the faculty and staff were spread across more than a dozen buildings on the peninsula south of San Francisco. It was clear that the department needed a permanent home, ideally in a single building.

The need to fund the construction of a computer science building prompted a search for potential sources of funding. One group targeted was alumni, and the department engaged them in several ways. More importantly, the department began to develop industry partners, creating connections and networks to industry that would prove crucial to its success over the years. The department would form the Computer Science Advisory Committee to connect senior executives into the department, and this committee also helped to shape the direction of the department in the years to come.

The department's growth in faculty and students put incredible pressure on the space available to the department. The department's main office space was in Polya Hall, and the division began with 2,610 sq. ft of space in 1961. Over the course of the decade, the office space expanded briefly to as much as 4,200 sq. ft., but would end the decade with only 3,380 sq. ft. in the building. The expansion of the Computation Center eventually cut into the space available to the department. Thus, on-campus space grew about 30% over the course of the decade (compared to a fivefold increase in the size of the budget and students in the department).[53]

The problem is that the Computer Science department had no space of its own on campus, and merely leased space (for free) from the Computation Center's home in Polya Hall. This required faculty to share offices and prevented the department from providing space to graduate students. For instance, in 1967 the Computer Science faculty noted that there were a total of two to four researchers in the department who had worked out of the chair's office over the past few months, and that they were "desperately short of space."[54] In response to the space problem, the university added 12,500 sq. ft. in additional space in the off-campus Powers

[53] Forsythe to Computer Science Advisory Committee, "Report on Computer Science Department," 19 Oct. 1970, Forsythe Papers, SC98/1/19.

[54] "The Future of Computer Science at Stanford," 8 Feb. 1967, Lederberg Papers, SC186/10/4.

building, but that space was 15 minutes away by driving, making it inconvenient for academic use.[55]

Forsythe began a lobbying campaign in earnest for the building, working with senior administrators to plan its financing and construction. In 1966, he discussed the issue of raising needed funds for the building, which were estimated at the time at $600,000. Government sources were not likely to support financing of the building, and so Forsythe was encouraged to create a visiting committee of people with interests in computation that would assist the department in setting its direction.[56] Forsythe continued to argue for the building through both official channels and other, more creative means. For instance, when one professor asks for a visiting professorship, Forsythe responded that "We have the degree of tolerance you need, but you can't imagine how bad the space situation is here," and told him that "I can almost promise you a desk." Forsythe blind carbon copied the letter to the president, provost and H&S dean.[57] Later, Terman would provide assistance in laying out an approach to raising funds for the building, whose costs were quickly increasing. He told Forsythe to break up the building construction into smaller phases, and he suggested that corporations would be willing to donate as little as $25,000 to as much as $800,000 toward a building. He also believed that

[55]Forsythe to Computer Science Advisory Committee, "Report on Computer Science Department," 19 Oct. 1970, Forsythe Papers, SC98/1/19.

[56]Forsythe to Money-raising file, "Meeting of 18 May 1966." 18 May 1966, H&S Files, SC36/8/"CS: 65-66."

[57]Forsythe to Formen S. Acton, 13 Sept. 1967, Sterling Papers, SC216/C1/14.

raising the funds would be tiring and would require a lot of energy for success[58]

One approach to getting financial support was reaching out to alumni. Forsythe encouraged the Computer Science faculty to increase their participation in alumni conferences, writing that showing up to the morning receptions "might even bring us money for a building."[59] Later, Forsythe would join the Committee on Education for Alumni, where the committee developed an idea for a "Portable Stanford" volume that would include articles written by faculty, such as on cybernetics. The committee also created educational programs for alumni such as speakers bureaus in major cities.[60] Interest from alumni played a role as the building construction got underway in the mid-1970s. The Alumni Association asked the department to teach several short courses on computers and society to alumni. For the department, the courses provided the opportunity to showcase the work of Computer Science to potential donors.[61]

In addition to alumni, the department created the Computer Science Advisory Committee in 1967 to assist it in setting a direction while engaging potential donors in the work of computer science. In developing the committee, Forsythe was told by the administration to place "strong computer scientists" on the com-

[58]Forsythe to Building Financing File, "Discussion with Terman, 7 Nov. 1969," 10 Nov. 1969, Miller Papers, SC208/3/1.

[59]Forsythe to File, "Alumni Conference, May 1968," 28 Dec. 1967, Forsythe Papers, SC98/14/15.

[60]Thomas Newell to Committee Members, "First Meeting of the Committee on Education for Alumni," 22 Apr. 1971, Forsythe Papers, SC98/2/2.

[61]"CS Department Faculty Meeting, Apr 13, 1976," 13 Apr. 1967, Lederberg Papers, SC186/5/2.

mittee. However, most of the people desired were alumni, trustees, "people with big money," and "managers of large corporations like banks." Even so, Forsythe was told by university administrators that the committee should be focused on the department's mission, and that it should not be used directly for fundraising.[62] Developing the membership definitely focused on the money aspect: one example included Ross Perot, who was both interested in computing and had "plenty of money."[63]

Forsythe and the university were relatively successful in their approach, and in 1970, the 15-member committee was composed of six academics, and several wealthy individuals, including the president of Varian Associates, the executive vice president of Bank of America, and the chairman of the Fireman's Fund Insurance Company.[64] Invitations to businessmen were often rejected due to potential conflicts of interest, but others like Fred Merrill of The Fund American Companies believed that the assignment was interesting and "can be of considerable value to our companies."[65]

While the committee may have been created to bring in donors, it also shaped

[62]Forsythe to Money-raising file, "Meeting of 18 May 1966," 18 May 1966, H&S Files, SC36/8/"CS: 65-66."

[63]Forsythe to Building-finance file, "Meeting: Miller, Forsythe, Ruetz - 7 Nov. 1969," 11 Nov. 1969, Miller Papers, SC208/3/1.

[64]Forsythe and Miller to the University Computer Facilities Committee members, "Invitation to Computer Science Advisory Committee meeting," 12 Jan. 1970, Lederberg Papers, SC186/4/1.

[65]Letters of rejection from chair of Texas Instruments and President of IBM, along with Merrill are in Sterling Papers, SC216/C1/15.

the department's policies and educational program. The committee's primary mission was to advise the university president on all matters related to computer science and computation at Stanford.[66] The committee's activities varied widely, from looking at the undergraduate and graduate programs to analyzing the finances of the Computer Science department. For example, the 1970 meeting included discussions of the time to PhD, the selection of introductory courses, the development of a professional master's program and admissions policies.[67] Later that year, Forsythe wrote in his report on "where you have helped us," that "your advice has encouraged us to move in certain directions." Those directions included creating a Computer Engineering master's degree, creating the Computer Forum, restricting the admissions of foreign students, and delaying the creation of an undergraduate major. Beyond this influence though, Forsythe also thanks the committee's assistance in terms of "actual gifts of money."[68] Thus, the committee had fulfilled both its official and unofficial missions: to direct the department and to serve as a source of revenue for major projects.

[66] Robert Lamar, Press Report. Stanford University News Service, 4 Oct. 1967, Forsythe Papers, SC98/1/14.

[67] Forsythe to CSAC File, "Impressions of advice to the Computer Science Department gained from meeting of 18-20 January 1970," 30 Jan. 1970, Forsythe Papers, SC98/1/18.

[68] Forsythe to Computer Science Advisory Committee, "Report on Computer Science Department," 19 Oct. 1970, Forsythe Papers, SC98/1/19.

## 3.5 Conclusion

The Computer Science department would spend nearly the entire decade pushing for more resources from the university. While the funds were never enough, the department managed to put together one of the strongest programs of computer science in the nation. Its success largely flowed from four important institutional factors: a strong relationship between the Computation Center and the Computer Science department, an entrepreneurial Computer Science faculty led by a bold leader, a flexible and generally supportive university administration, and a need to seek out additional funding to pay for a new academic building and an expanded budget.

The desire for additional funding led to a pragmatic Computer Science faculty that created new programs to engage industry and admitted additional high-paying industry students into the department's educational programs. Along the way, such programs built the first university-industry networks between professionals in computation in the area known as Silicon Valley, networks that would build the world's most notable regional innovation hub. It is this part we turn to next.

# Chapter 4

# The University-Industry Nexus

Since the middle of the twentieth century, Stanford University has developed a reputation as an industry-facing university, and by the 1970s, it was serving as a model of the academic-industry complex desired by many higher education leaders. The school receives more royalties from technology licensing than almost any other university in the country, and it has proved to be a successful incubator of technology companies, including Hewlett-Packard, Varian Associates, SUN Microsystems (whose name is an acronym for Stanford University Network), Yahoo!, and Google.

This friendliness to industry was not initially the case for the Computer Science program at Stanford. The division grew out of a desire to expand the theory of computer science, and industry connections seemed largely irrelevant to that goal. That attitude would change as concerns about funding increased in the initial years of the Computer Science division before 1965. There was a constant perception during that period that Stanford's computer science efforts lacked the kind of major funding received by its peer schools in the east.[1] The Computer Science faculty, and particularly Forsythe, believed that MIT was receiving significantly more funding from the federal government and that philanthropic foundations were awarding universities like Cornell and the University of Michigan with significantly larger grants.

[1]The actual details of the finances matter less than the perception of the faculty in terms of its effect on academic culture.

Furthermore, a large host of negative financial trends toward the end of the 1960s forced the faculty to engage with industry in pursuit of new revenue sources that could be used for the continued expansion of the Computer Science department. This created pressure on the Computer Science faculty to secure alternative sources of revenue to compete in the quickly expanding field of computer science, and the largest source of this funding would eventually come from industry.

The development of ties between the Computer Science department and the computation industry was the beginning of the network that has shaped the course of economic growth in Silicon Valley in recent decades. At the core of this network is the circulation of talent between Stanford and industry that allowed for a constant exchange of new ideas that mutually informed the work of both sides.

Within this partnership of academia and industry, though, lies a tension at the heart of the goals of both sides. Universities have traditionally defined themselves as facilitating the discovery of basic science, the first stage in the linear model explicated by Vannevar Bush.[2] Faculty and scientists in such institutions are to focus exclusively on expanding the current range of human knowledge, without concern for the utility of such knowledge. On the other hand, the linear model designates industry as the translator of basic science research into applied science and product development. Industry sits between the repositories of knowledge

[2] Vannevar Bush, "Science: The Endless Frontier," United States Government Printing Office, 1945, `http://www.nsf.gov/od/lpa/nsf50/vbush1945.htm#summary`

discovered by universities and the desires of potential customers, and it attempts to use the former to satisfy the latter (while also generating economic profit).

The primary difficulty with the linear model is that research can rarely be divided into "basic science" and "applied science." History is replete with examples of technological innovation and fundamental knowledge acquisition that occurred in both basic and applied laboratories. This overlap is particularly noticeable in computer science, where even highly theoretical algorithms can oftentimes find a practical use.[3]

Thus, to develop a more encompassing picture of the web of influences between the Computer Science program and industry, a more sophisticated model is needed. The contextual model shows that all three components of research — science, technology, and society — provide their own influence and together, mutually shaping the outcome. Thus, analysis needs to include the relations between all of them in order to provide a complete portrait of how the network affected the development of new scientific knowledge or technology.

This chapter investigates the role of industry in the Computer Science programs at Stanford, and how the Computer Science department adapted to engage industry. This chapter argues that the department created venues of engagement that allowed for the circulation of talent that spread crucial ideas between the

[3]One example is the theory of sparse matrices (matrices with a high proportion of 0s in them), which would later prove crucial in Google's PageRank system

university and industry. Along the way, these relations provided direct financial benefits to the department, either in the form of money or equipment. Thus, the growth of university-industry relations served several different purposes for each of the organizations in the network.

This chapter begins by looking at the first industrial grant to the Computer Science division, a grant of a few thousand dollars provided by the DuPont company. The themes seen in these first grants will become more concrete in the extensive grants received by the Computer Science department starting in 1965 as explained in the. Among the most important industrial relationships was with IBM, who provided millions of dollars to Stanford in grants, equipment and other benefits. While these one-to-one relationships certainly assisted the department, it was the creation of venues to engage industry that had the largest effect on creating networks and influencing the direction of the department. This chapter concludes by examining the development of the Honors Co-op program, which provided a means for industry engineers to take classes at Stanford conveniently, as well as the Computer Forum, which developed a conference for faculty and top industry engineers to meet and discuss research, as examples of these kinds of venues.

## 4.1 Industry Funding

The motivations behind industry donations to Stanford donations varied. A major theme of the era was the incredible manpower shortage of programmers,[4] and some businesses felt the need to develop direct relationships with universities to guarantee the ability to recruit talent. Second, competition between companies was fierce, and each company offered computer products that were mostly incompatible with the systems of their competitors. Thus, encouraging the adoption of particular equipment at top computer science departments was seen as creating favorable conditions for the adoption of a particular computer architecture.

More generally though, companies believed that expanding the frontier of knowledge in computers would provide new theories for potential profit and product development. Thus, they occasionally wanted to directly fund innovation in the nascent field. Creating relationships with academic institutions could provide an early glimpse of developing theories, and thus provide a lead over competitors. Whatever the reasons of a particular company, industry as a whole played a crucial supporting and shaping role that directed the course for the developing Computer Science department at Stanford.

This section will first look at the relationships with Stanford of several different companies, most notably IBM,that played a critical role in the development

[4] See Louis Fein, "The Role of the University in Computers, Data Processing, and Related Fields," Communications of the ACM, Vol. 2, No. 9 (Sept. 1959), pg. 7-14.

of the Computer Science division and after 1965, the Computer Science department. These connections were variable depending on the goals of the company, and the ways they shaped the department often reached far beyond just monetary donations, including supplying computers and human talent that fundamentally altered the research program at the university. This section starts with Stanford's first grant from DuPont, which demonstrates many of the benefits, but also the risks, that comes from industry funding.

### 4.1.1 DuPont and the Division

One of the greatest challenges faced by the Computer Science division in the early years was securing a stable teaching budget. In the 1963-1964 academic year, the division had a teaching budget of just $48,000.[5] The first external industry grant received by the division came from the DuPont Corporation, a major chemical corporation with broad interests in engineering education and research in university settings. Beginning in 1963, DuPont donated $18,000 a year to Stanford, and required it to be split between chemistry, biochemistry and undergraduate teaching in engineering. The share received by the Computation Center began at $4,000 in 1963, and increased to $5,000 in 1964.[6]

[5]For details, see chapter three

[6]It is not clear from the archives if the gift was to the Computer Science Division or to the Computation Center; Forsythe's accounting practices likely plays a role in this confusion. Richard Bates to Raymond Bacchetti, "Report to DuPont," 19 Jan. 1965, H&S Files, SC36/8/"CS: 64-65."

The DuPont funds were directed toward teaching and represented almost 10% of the Computer Science budget in the early years. The funding was roughly equivalent to the budget for half of a professorship, but with the joint professorships often created, this funding essentially provided another faculty slot for the division. In a typical report on the grant to DuPont, Forsythe stressed both the critical nature of the grant and the importance the division placed on undergraduate teaching, writing that "we know that the future of computing depends on inspiring youngsters."[7] Given the ingratiating nature of such reports, DuPont seems heavily interested in using its funds to develop possible pools of scientific talent.

The DuPont grant also illustrates one of the major problems with relying on industry partners for revenue:it can often be capricious and disappear with little warning. Frederick Terman placed the grant in the base budget of the department, making it equivalent to H&S teaching funds and other sources of grants as a source of stable funding. Unlike those revenue sources however, the DuPont grant was not automatically renewed each year. The department's dependence on the grant became clear in the 1966-67 and 1967-68 academic years when DuPont decided against renewing the grant, and did so without warning to the university. According to a member of the secretary's office of Stanford, DuPont assessed its own interests in choosing where to give funding, and did not take requests from institutions. Unlike federal funding mechanisms, there was no established procedure

[7]Forsythe to Julian W. Hill, 3 Feb. 1965, Terman Papers, SC160/3/12/2.

for receiving the grant in the first place. To secure a grant, the secretary wrote that "If some institution in a given year is fortunate enough to fall within the orbit of [the company's interests], then its chances for DuPont support are improved."[8] Computer Science thus had to make up for two years worth of lost revenues with little ability for recourse.

### 4.1.2 Corporations and the Department

Given the theoretical focus of the Computer Science division, the Computer Science faculty had not developed significant connections to industry. With the creation of the department in 1965 and the further expansion of computing as an industry, the possibility of connections increased tremendously.[9] Within just five years, the department would receive more than a million dollars in direct funding from industry, in addition to creating several bureaucratic venues for engaging industry within Stanford. This section looks at the largest computing corporations of the time and their relationships with Stanford. Through funding, donated equipment, borrowed talent and other support, the Computer Science department would come to play a mutually advantageous role in the ecology of industrial innovation for these companies.

[8]Provost's Office to Russell Worley, "Budget of the Computer Science Department," 25 Sept. 1967, H&S Files, SC36/89-114/"CS: 68-69."

[9]Although it is hard to judge, the increased stature of a department over a division likely played a role in this increase.

**Corporate Direct Funding**

No other corporation played as vital a role to the financial and intellectual development of the Computer Science department as IBM. IBM not only began to think about the possibility of grants early, but the company was also prepared to make very large donations to universities beginning research programs in the burgeoning field. One example comes from early 1962. Albert Bowker, the Dean of the Graduate Division at Stanford, applied for a $100,000 annual grant from IBM that would have been split three ways. Teaching would receive $30,000 a year—almost doubling the current teaching budget at that time. In addition, Bowker requested $30,000 to support research on systems for the the IBM 7090, directing the grant proposal right at the core of IBM's corporate interest. Extending this, he also requested $40,000 for unrestricted research funds, and listed a litany of projects that the money might go to, emphasizing that funds would go to "imaginative and creative applications, not routine ones" and that the funds would be used particularly to start new projects.[10] The grant was not received, but this example shows the level of funding possibly available to a research area that had yet to develop into an independent academic division of Stanford.

The university, though, would continue to pursue grant opportunities from IBM, and those efforts proved successful in 1967 when the company approved

[10]Letter from Bowker to C. R. De Carlo, 2 Mar. 1962, H&S Files, SC36/89-114/8/"CS: 62-63."

a $1 million grant to be paid out over four years. The size of this grant was extraordinary given the size of other revenue sources for the Computer Science department at the time, and perhaps unsurprisingly, the talks surrounding the grant were described as a "somewhat unusual negotiation."[11] Thomas J. Watson, Jr. the chairman of the company's board, wrote Stanford's president J.E. Wallace Sterling with the decision. IBM's rationale for providing such a large amount of funding included the desire to support additional research in systems and advanced computing applications, and Watson added also that "our people in the IBM Scientific Center in Palo Alto look forward to continuing their close technical liaison with your people."[12] This desire to connect theoretical researchers in the academy to the technical personnel in nearby industrial labs was a constant feature of Stanford's relationship with industry.

President Sterling emphasized in his acknowledgement of the grant that the funding would be used to connect the Computer Science department with other departments across the university,a goal of interdisciplinary research that was typical of IBM's approach.[13] This teaching grant was not the only major source of funding from the company with interdisciplinary research as its goal. IBM also influenced the department through funding new research programs. Stanford Law

[11]Frank Newman to John Herriot, "IBM Grant," 18 May 1967, H&S Files, SC36/8/89-114/"CS: 66-67."

[12]T. J. Watson, Jr. to J. E. Wallace Sterling, 9 May, 1967, H&S Files, SC36/8/89-114/"CS: 66-67."

[13]J.E. Wallace Sterling to T. J. Watson, Jr., 23 May 1967, H&S Files, SC36/8/89-114/"CS: 66-67."

School developed a Law-Computer Fellows program that would explore how computers might affect the legal environment, and the costs of that program were underwritten by a $255,000 grant by the company.[14]

Evidence suggests that IBM hoped to enhance its own competitiveness by influencing Stanford's research and services, and thus, the company's intentions were not entirely pure. The desire to protect core corporate interests was a major motivation of the funding and relationship-building the company conducted. One example of this desire comes from the early history of the Computation Center. In late 1963, Forsythe received a letter from a manager at the Service Bureau Corp. a commercial computation center fully owned by IBM. The company was concerned that Stanford was potentially offering its computation resources to commercial clients, and the company felt that it could not compete with the low prices and excellent service offered by Stanford.[15] Forsythe told the company that Stanford's Computation Center was not engaged in commercial computation, and felt that the company's request to desist was a little out-of-place.[16]

IBM's enormous funding was a massive boon to Stanford, and indeed, it is unlikely that the department could have achieved its growth in student enrollment without this significant source of external revenue. As seen with the DuPont example though, creating a balanced array of revenue sources was crucial for income

[14]T. J. Watson, Jr. to J.E. Wallace Sterling, 3 Sept. 1968, Miller Papers, SC208/3/29.

[15]W. A. Wasson to Forsythe, 18 Oct. 1963, Sterling Papers, SC216/1/1/27.

[16]Forsythe to IBM File, "Visit from Warren Wasson," 10 Oct. 1963, Sterling Papers, SC216/1/1/27.

stability, and Stanford pursued funding from other corporations as well.

One source of revenue Stanford used was its extensive network of engineering alumni. The quintessential pair was William Hewlett and David Packard, who had long and deep relationships with Stanford beginning with their undergraduate education in the 1930s. Hewlett-Packard (HP) would take an early and enduring interest in computing, becoming one of the early industrial leaders of the field. The Computer Science faculty were well aware of the importance of the relationship between the department and the company, and established an HP liaison committee —the only company to have a standing committee of the department by 1975.[17]

While HP's gifts were generally in the form of computers, David Packard also had an on-going personal relationship with the department as the board of trustees representative on the Computer Science Advisory Committee described in chapter three. Packard himself would donate a significant amount of funds to the department's projects, including a $50,000 gift in 1969.[18] A member of the committee felt that the donation to computer science education stemmed directly from the work that Packard did with the committee, giving the issues facing the department increased visibility (and simultaneously representing one of the larger successes of

[17]See "Computer Science Department Committee Memberships 1974-1975," Lederberg Papers, SC186/5/2.

[18]Robert Langle to Robert Vandagriff, "Investment of Funds," 21 Nov. 1969, H&S Files, SC36/89-114/8/"CS: 69-70."

the main goal of the committee).[19]

### Donated Equipment

Outside of the personal relationship between Packard and the department, HP itself provided significant resources into the department, following a similar corporate investment strategy to IBM. HP, like other computing companies, faced an incredible shortage of recruits for its business. The company donated an HP2116A computer for student use and helped to fund a departmental research assistantship that would focus on developing software for the new machine.[20] HP was quite upfront with its intentions for the donation. Forsythe wrote that HP "may later try to market it, and would like some experience with its use," and he does not believe that "they expect production programming, but really hope to get some experience, criticism, and some intangible award."[21] Computer Science faculty were also encouraged to make trips to HP to comment on the technology and research programs, creating a circulation of scholars.[22]

However, donations of equipment were sometimes controversial when attached to closely to corporate research agendas. This was particularly the case of joint research programs, where the worlds of basic and applied science appeared to most closely meet. One notable example of this type of controversy was in the summer

[19]F. J. Weyl to Forsythe, 20 Mar. 1969, Forsythe Papers, SC98/1/17.
[20]John Herriot to WF Cavier, 5 Oct. 1966, Miller Papers, SC208/2/14.
[21]Forsythe to HP File, 19 Apr. 1966, Miller Papers, SC208/2/14.
[22]Bernard M. Oliver to W.F. Miller, 12 Nov. 1968, Miller Papers, SC208/2/14.

of 1970, when the Standard Computer Corporation developed a potential joint research project with the university. As part of the agreement, the company would donate more than $1.1 million in equipment to the Computer Science department, with both sides offering personnel to explore research on the equipment.[23] The goal for the company was to develop computer science as a field, and more importantly, to "promote the development of software and other computer science tools usable with Standard's computer systems and taking particular advantage of the microprogramming capabilities as are now being manufactured by Standard."[24]

At the heart of the faculty's concern was whether Stanford should accept research proposals from industry. Complicating the issue were faculty who actively desired to work on the equipment, and thus the definition of faculty interest was blurry. Nonetheless, the university administration emphasized the need for university research to come "fundamentally from faculty interest —not in response to a [research project] quote."[25] In the end, despite strong support from some Computer Science faculty, the university rejected the entire offer and moved away from direct computation research on behalf of a corporation.[26]

[23]Sidney Drell to Howard Hooper, "Proposed Joint Study Agreement between Standard Computer Corporation and Stanford University," 6 Aug. 1970, Miller Papers, SC208/1/31.

[24]"Agreement concerning joint research and study program," 1970, Miller Papers, SC208/1/31.

[25]Niels J. Reimers to John F. Olson, 28 July 1970, Miller Papers, SC208/1/31.

[26]Perhaps no other event indicates that the department had reached financial security by 1970. Today, it seems unlikely that a university would turn down an equivalent $6.1 million gift. See Daniel S. Greenberg, Science for Sale: The Perils, Rewards, and Delusions of Campus Capitalism, University Of Chicago Press, 2007.

**Circulating Talent**

IBM's influence and shaping of the Computer Science department did not stop at just funding, but also took place through person-to-person interaction facilitated by the company. An early example of this kind of interaction was the development of a position for Arthur Samuel, described as one of the "vigorous leaders in research on artificial intelligence."[27] Samuel was retiring from IBM and interested in continuing his research on machine learning at a variety of institutions, including MIT and Stanford. Forsythe developed a unique arrangement to persuade him to join the department, including additional consulting days per week and a reduced course schedule.[28] Unlike some of the university's decisions, Stanford handled the negotiations rapidly, and Forsythe offered Samuel the position of senior research computer scientist just four days later with funding from three separate grants.[29]

Samuel would play an important role in the department's artificial intelligence projects, but also helped to shape the department's relationship to industry. He gave a presentation about the Computer Forum to the Computer Science Advisory Committee, the department's visiting board of advisers, and he encouraged the Computer Science faculty to reach out to the research and operating departments and avoiding the corporate staff when finding contacts for the forum.[30] The

[27]Forsythe to Hubert Heffner, "Employment of Arthur Samuel," 4 Feb. 1966, H&S Files, SC36/89-114/8/"CS: 66-67."

[28]Ibid.

[29]Forsythe to Arthur Samuel, 8 Feb. 1966, H&S Files, SC36/89-114/8/"CS: 66-67."

[30]Forsythe to File, "My notes on the Computer Science Advisory Committee meeting of 6-8

interaction between the department and IBM also included active staff. For example, Ted Rivlin, an active research scientist at IBM, was provided a visiting professorship paid jointly by Stanford and the company.[31]

Outside of IBM and HP's donated equipment, Forsythe attempted to create an environment of cross-pollination between the Computer Science department and industry. The goal was both to increase the quality of the research program and to engage potential donors in the mission of the department. Bell Laboratories played a significant role in creating this sort of academic-industry circulation. The company helped to subsidize the costs of having its researchers join Stanford as visiting faculty, allowing the department to expand the number of faculty slots for minimal cost while providing some of the company's top engineers with an intellectually stimulating environment.[32]

Other notable researchers like Richard Hamming, who helped to form the field of coding theory, requested sabbaticals from Bell Labs to go to Stanford. In fact, Forsythe was told by Bell's leadership that the department needed to do more to attract its researchers, saying that the school's peers were more aggressive in securing visiting professors.[33] At least at Bell, the movement of researchers

October 1968," 25 Oct. 1968, Forsythe Papers, SC98/1/16

[31]Forsythe to CSD Faculty, "Visitors, faculty appointments, and new courses," 18 July 1969, Miller Papers, SC208/3/17.

[32]Forsythe to Sears file, 'Conference with Royden 4 June 1965," 10 Jun. 1965, H&S Files, SC36/8/"CS: 65-66."

[33]Forsythe to Tenure Faculty, "Bell Laboratories as a source of colleagues," 7 Feb. 1969, Forsythe Papers, SC98/14/10.

was generally initiated by the people themselves, and not by corporate leaders. Forsythe was told that Bell does not "ration" personnel to universities, but rather its researchers request leave from their superiors who will consider the request.[34]

### Other Connections

These industry connections also facilitated the recruitment of students, as well as providing them with interesting opportunities. Texas Instruments gave a presentation of its company's research in late 1969 and held a series of exchanges with faculty and researchers at the Computation Center, AI Lab and SLAC. In addition, the visiting representatives also interviewed students, providing a convenient means for securing employment.[35] IBM also desired to create connections with students. In addition to developing relationships through the Computer Forum, IBM offered such gifts to students as tickets to the American Ballet Company.[36]

IBM was not just interested in recruitment, but also desired to develop the nascent field of computer science. An example of this kind of approach was the development of an "IBM Postdoctoral Fellowship" in 1971. William F. Miller, a professor in the department, received a note from the IBM San Jose Laboratory stating that the lab was trying to contribute to a " 'science' of computers" and that the lab wanted to support the creation of a postdoctoral position that would help

[34] Ibid.
[35] "Texas Instruments Presentation," 12 Dec. 1969, Miller Papers, SC208/1/6.
[36] Steven A. Baffrey to W.F. Miller, 19 Jun. 1970, Miller Papers, SC208/2/11.

to develop this area.[37] Supporting students through these postdoctoral grants thus provided access to up-and-coming researchers for recruitment while also expanding the "core" of computer science.[38]

Developing these connections with industry often required high-level support from the Stanford administration, and the department often received it. The president played an important role in developing these relationships. When Cuthbert Hurd wanted to discuss the far reaching implications of Computer Science, Heffner wrote to President Sterling's aide that "Incidentally, Hurd is potentially a major donor to computer activities at Stanford."[39] Hurd would eventually get his meeting with the president, and later would chair the Computer Science Advisory Committee. In the other direction, Sterling reached out to industry. When the Burroughs Corporation, a major manufacturer of computers, began an expansion on the West Coast, Sterling introduced himself and almost immediately requested "the financial support" of the company to benefit the university.[40]

Throughout this discussion, we see the tremendous impact of a handful of companies on shaping the development of the Computer Science department. Whether in terms of academic programs, such as the Computer-Law Fellows program sponsored by IBM, or the circulation of experts between industry and academia such

[37] A. H. Eschenfelder to William F. Miller, 1 Mar. 1971, Miller Papers, SC208/2/11.

[38] Forsythe to Dantzig, Feigenbaum, Floyd, Knuth, McCluskey and McCarthy, "IBM Postdoctoral Fellowship," 15 Mar. 1971, Miller Papers, SC208/2/11.

[39] Heffner to F. O. Glover, 13 Feb. 1967, Sterling Papers, SC216/C1/15.

[40] J.E. Wallace Sterling to Ray W. Macdonald, 8 Jan. 1968, Sterling Papers, SC216/C1/14.

as from Bell Labs, the department's direction was heavily shaped by the desire to engage industry and support work of mutual interest.

## 4.2 Developing Venues for Industry

While Stanford tended to have formal arrangements only with the largest corporations, the Computer Science department created two venues of engagement that provided alternative means for other companies to interact with the department. First, the Honors Co-Op program was a special master's program that allowed employees of local companies to take computer classes in a convenient, ad-hoc fashion. Second, and most critically to the development of the department, the Computer Forum was created to provide a conference to showcase the latest work of the Computer Science faculty to top industry scientists. Both programs provided significant funding to the department and were crucial to the financial stability of the department.

### 4.2.1 The Honors Co-Op Program

The speedy development of computer science in the 1960s created an acute manpower shortage of academic computer scientists and programmers. For companies that required such talent, there are a couple of different approaches they can use to solve this problem. One approach was to create better relationships with computer science departments, whereby a company would get access to new graduates ahead of the competition. Another approach was upgrading the skills of existing company employees, some of whom may have an educational background close to computer science. While companies in the industry desired to increase the number of employees trained in the field, most could not afford to lose employees for one to two years to a master's program, either in terms of tuition or the opportunity cost of lost productivity.

Stanford developed a program to address this issue known as the Honors Co-op program. Modeled after similar programs in Stanford engineering (particularly electrical engineering), the program allowed employees of industrial affiliates to take classes part-time, generally one or two at a time while paying a higher level of tuition than typical for the administrative convenience.[41] The program first appeared in 1963, and in its first year it taught sixteen students from industry for a total of 185 units.[42] Income that year totaled $3,258, or about $17.61 a unit.[43] The program expanded quickly, more than doubling revenue in the next academic year to $7,260, an amount that could pay for the department's share of a joint faculty member.[44]

---

[41] Forsythe, "State and Plans of the Computer Science Department: A report to the Computer Science Advisory Committee," 7 Oct. 1968, Forsythe Papers, SC98/1/16.

[42] Royden to McGhie, "Honors Co-Op Funds for Computer Science," 17 Oct. 1963, H&S Files, SC36/89-114/8/"CS:63-64."

[43] L.F. McGhie to Royden, "Honors Cooperative Funds for Computer Sciences," 30 Oct. 1963, H&S Files, SC36/89-114/8/"CS:63-64."

[44] Robert Langle to Forsythe, "Status of CSD Honors Cooperative Fund," 29 Oct. 1965, H&S Files, SC36/89-114/8/"CS:65-66."

Conflicting priorities over the direction of education in the department, however, soon caused the program to stall. At the very first faculty meeting of the new Computer Science Department in January 1965, Forsythe asked whether students who were not making degree progress in the Honors Co-Op program should continue to be allowed to register for classes.[45] Due to the lack of faculty, there was a desire by members of the department to focus more attention on doctoral candidates, which provided the visibility and prestige that the department desired. However, the university administration wanted the additional revenue that the Honors Co-op program provided, particularly because the Computer Science budget was so dependent on soft money provided by the university. The potential growth of the income was considered "spectacular" and the income was used to pay for a variety of expenses, such as the department's secretary.[46]

With control of the admissions policies though, the department's faculty won over the university administration, and the department soon throttled the number of graduates into the Honors Co-op program.[47] However, the administration was not responsive to the changing admissions profile, and started to budget the Honors Co-op program's income directly into the budget base of the department. This issue reached a climax in 1968 when the lack of income became apparent, and the

[45]Forsythe to File, "Meeting 5 January 1965," 19 Jan. 1965, Forsythe Papers, SC98/15/1.

[46]Royden to Terman, "Missing salary for Diana Saunders," 21 June 1965, Terman Papers, SC160/3/12/2.

[47]Forsythe, "State and Plans of the Computer Science Department: A report to the Computer Science Advisory Committee," 7 Oct. 1968, Forsythe Papers, SC98/1/16.

department's budget faced cuts. Forsythe was unhappy at the prospect of cuts, writing in his notes that "no one ever asked us to keep our HCP program going strong; there has never been the slightest intimation that our budget depended on it."[48] When Forsythe discussed the matter with the Computer Science Advisory Committee that year, he asked whether throttling admissions had been a "mistake."[49] Repeating earlier arguments, he was told by Albert Bowker, the dean of H&S, that the program should be kept for the revenue.[50]

The Computer Science faculty were more receptive to Bowker's argument this time, as the need for revenue became particularly acute in the late 1960s and early 1970s. The department began actively building up the program once again. First, the department developed a closed-circuit television system that would allow for the taping of classes that could be watched by employees at their convenience, allowing the program to adapt to work schedules better.[51]

More importantly, the department began to develop an interdisciplinary master's program in Computer Engineering. The program was designed for Honors Co-op students, and there was even discussion of limiting the program to only those students.[52] Intellectually, the need grew out of the growing split between

[48]Forsythe to Royden file, "Meeting of 28 October 1968," 28 Oct. 1968, H&S Files, SC36/8/89-114/"CS: 68-69."

[49]Forsythe, "State and Plans of the Computer Science Department: A report to the Computer Science Advisory Committee," 7 Oct. 1968, Forsythe Papers, SC98/1/16.

[50]Forsythe to File, "My notes on the Computer Science Advisory Committee meeting of 6-8 October 1968," 25 Oct. 1968, Forsythe Papers, SC98/1/16.

[51]Forsythe to Computer Science Advisory Committee, "Report on Computer Science Department," 19 Oct. 1970, Forsythe Papers, SC98/1/19.

[52]G.H. Golub and E.J. McCluskey, "Degree of Master of Science in Computer Engineering: A

the fields of computer science and that of software engineering, "even though," as Forsythe wrote, "an aspect of computer science is concerned with software."[53] The approach began to increase the co-op funds, which reached around $8,000 in 1970 and were expected to increase in the coming years.[54]

### 4.2.2 The Computer Forum

Perhaps no element of the Stanford Computer Science department more embodies the the development of networks between academia and industry than the Computer Forum, a membership-based conference that provided a common environment between industry scientists and the department's faculty members. Through these conferences, industry provided insight to the members of the department on the issues facing their companies, and Computer Science faculty updated industry partners with new information on the forefront of their research. Along the way, faculty became more involved in the work of individual companies, in some cases forging consulting ties with them, and in other cases simply developing an open line of conversation.

The development of the program began in late 1968, mostly as a response to the difficult budget situation faced by the department as well as Stanford. The

Proposal," 19 Jan. 1970, Forsythe Papers, SC98/1/18.

[53]Forsythe to Software Engineering file, "Perlis's Remarks in Boston," 19 May 1969, Forsythe Papers, SC98/14/9.

[54]Forsythe to Computer Science Advisory Committee, "Report on Computer Science Department," 19 Jan. 1970, Forsythe Papers, SC98/1/18.

department needed to increase the amount of "hard money" it secured, and one avenue for doing so was increasing money from industry. The Honors Co-op program covered the educational needs of industry, but there was increasing desire to share the theoretical insights gained by the department's faculty with industrial partners. The Computer Forum was variously described in brochures as a "Stanford-industry-business program" and was successful quite early in attracting industry members. Part of the support came from members of the Computer Science Advisory Committee, which created a subcommittee to follow the development of the forum chaired by David Packard, himself one of the most important industrialists of the era.[55]

The development of the Computer Forum was slow in the initial months, blamed on the lack of a strong leader to implement a vision for the program.[56] Forsythe agreed to the program in early 1968, but feared that the program would fall into the trap faced by a similar program at MIT, by which "non-professional" faculty (by which he meant faculty without an understanding of industrial goals) headed it "from the start."[57] These fears seemed to have delayed implementation of the program, but by the the end of 1968, a handful of qualified people took the leadership. Among them was Ed McCluskey, who was jointly appointed

[55]Forsythe to File, "My notes on the Computer Science Advisory Committee meeting of 6-8 October 1968," 25 Oct. 1968, Forsythe Papers, SC98/1/16.

[56]Forsythe, "Notes on Lunch with Linvill," 25 Feb. 1969, Forsythe Papers, SC98/2/38c.

[57]Forsythe to Affiliates File, "CSD-EE Affiliates Program," 14 Mar. 1968, Forsythe Papers, SC98/14/15.

between Electrical Engineering and Computer Science and helped to develop the program as a joint operation between those two departments. In addition, William F. Miller assisted in building organizational support. However, a large influence came from Arthur Samuel, the retired IBM researcher who had recently joined the department as a senior research computer scientist.[58] Stanford's earlier development of connections to industry thus proved to be a critical element in Computer Science's further success in attracting partners to the department. One of the major successes in launching the program was building a faculty team with natural connections to industry, and all three individuals had them.

One of the major insights of the program was focusing on technical-level relationships. This emphasis was communicated strongly by the university, such as when President Kenneth Pitzer, a noted chemist, began outreach to Fairchild Semiconductor: "our Computer Forum is intended to encourage a working relationship between peers in the laboratories of the industrial participants and of Stanford participants; it is not intended to be a corporate-level relationship."[59] Stanford's promotional brochure further explained the best kind of representative from corporate affiliates: "These people should have a broad view of the company's interests, but should be close enough to the technical work to benefit and contribute to the technical meetings and informal discussions."[60] By limiting the

[58]Forsythe, "Notes on conversation," 10 Jan. 1969, Forsythe Papers, SC98/2/38c.
[59]Pitzer to Kay Magleby, 25 Nov. 1969, Lyman Papers, SC215/1/"CS: 68-71."
[60]Brochure: "The Stanford Computer Forum," Undated, Feigenbaum Files, SC340/13/26.

scope of the type of person who should come to the forum, Stanford created a venue that focused on fundamental research issues, which was more valuable to the department than an executive meet-and-greet.

The first meeting of the Forum was held in May 1969, and it was attended by representatives from seven companies who together paid $16,000 in dues for a one-year membership.[61] Forsythe noted that the amount of money was "already playing an indispensable role" in the department's budget, and the desire was to increase the amount to $24,000 by 1971.[62] Expenses for the meeting were remarkably small: the fourth annual meeting cost less than $1,000 to execute.[63] The success of the first meeting encouraged other faculty members to begin recruiting industry partners, such as Gene Golub, the numerical analyst.[64]

From this beginning, the program grew rapidly with the strong involvement of the Computer Science faculty. Dozens of potential companies were contacted, and lists were maintained of other potential companies (with particular attention paid to companies that were corporate sponsors of the ACM).[65] The department

[61] The companies were Bank of America, General Electric, General Motors, Hewlett-Packard, IBM, RCA and Xerox. There was a single flat fee for each organization. Forsythe to Computer Science Advisory Committee, "Report on Computer Science Department," 19 Jan. 1970, Forsythe Papers, SC98/1/18.

[62] Ibid.

[63] Sally Burns to Computer Forum Committee, "Expenses Incurred for the Fourth Annual Meeting," 9 Mar. 1972, Feigenbaum Papers, SC340/13/15.

[64] Forsythe to Senior Faculty File, "Notes on meeting of 2 Feb. 1970," 3 Feb. 1970, Miller Papers, SC208/2/13.

[65] Examples: Forsythe to Senior Faculty File, "Notes on meeting of 2 Feb. 1970," 3 Feb. 1970, Miller Papers, SC208/2/13; Sally Burns to Computer Forum Committee, "Minutes of Meeting of 21 Oct. 1970," 22 Oct. 1970, Miller Papers, SC208/2/12.

expected the forum to increase from the initial seven members to fifteen, and later, to twenty members in their promotional brochures.[66] However, the quickly increasing number of companies that joined the forum did not mean that some members did not leave. Bank of America would leave after the fourth annual meeting since they felt that the lack of a joint program between the department and the business school was not serving their needs.[67] Nonetheless, the program proved quite capable of attracting new members (perhaps assisted by the department's policy of offering a "finding fee" to faculty who brought new members to the forum).[68] By the end of the decade, there were 23 members, and the department agreed to increase annual membership fees to $9,000— a total of about $207,000 of revenue from the program every academic year. In addition, the initial membership was extended to a minimum of five years —providing a rare source of stable income to the department.[69]

The success of the program cannot be judged just in terms of revenue, but must include the creation of new connections between the department and industry. At the heart of the program's goals was to generate a conversation between industry and academia and provide a structured informal conversation for exchanging ideas.

[66]Brochure: "The Stanford Computer Forum," Feigenbaum Files, SC340/13/26; Brochure: "The Stanford Computer Forum," Miller Papers, SC208/2/12.

[67]Sally Burns to Computer Forum Committee, "Minutes of meeting of Feb. 18, 1972," 13 Mar. 1972, Feigenbaum Papers, SC340/13/15.

[68]Floyd to Computer Forum File, 28 Oct. 1975, Feigenbaum Papers, SC340/13/17.

[69]Betty Scott to Computer Forum Committee, "Meeting of Oct. 31, 1974," 11 Nov. 1974, Feigenbaum Papers, SC340/13/16.

The department argued that the program would provide "relaxed contacts with faculty and graduate students" and "the opportunity to hold informal discussions with faculty members and to influence trends in computer education" for industrial members, and reciprocally, Stanford would receive insight into pressing business problems.[70] This goal was translated into action: for example, the forum meeting in February 1971 included five panel discussions chaired by faculty, but also space for individual appointments and a beer party.[71] Faculty were heavily encouraged to attend both technical and social events.[72]

These individual contacts with faculty and graduate students proved useful to companies. Faculty were encouraged to visit companies at their engineering laboratories, a part of the benefit of membership in the forum.[73] One example comes from the fourth annual meeting in February 1972, where Robert Floyd was asked to begin a consulting relationship with Xerox after the company's representative had a fruitful talk with him at the Forum.[74] Companies also benefited from interacting with graduate students. February was an ideal time for the meeting, as graduate students were ready to begin finding employment in industry. Given the serious lack of candidates for positions, early access to graduates was likely a

[70]Brochure: "The Stanford Computer Forum," Feigenbaum Files, SC340/13/26.

[71]Forsythe to Meetings file, "Meeting of 11 Jan. 1971," 13 Jan. 1971, Miller Papers, SC208/2/11.

[72]John F. Wakerley to Computer Science Faculty, "Stanford Computer Forum Meeting," 24 Jan. 1975, Feigenbaum Papers, SC340/13/26.

[73]Ed McCluskey to CS/DSL Faculties, "Reimbursements for faculty visits to Forum companies," 13 Jan. 1978, Feigenbaum Papers, SC340/13/15.

[74]Peter J. Warter to E. J. McCluskey. 15 Feb. 1972. Feigenbaum Papers, SC340/13/15

significant factor in the development of the Computer Forum.[75]

The Computer Forum brought industry into close and regular contact with the faculty of Stanford. The program provided significant and stable revenue to the department, allowing it to expand its teaching mission, while also providing important benefits to industry in the form of intellectual connections. The networks that developed between the two were strong, and helped to cement Stanford's reputation in the computing world.

## 4.3 Conclusion

One of the core issues facing the Computer Science department was developing a significant source of stable income. Creating faculty positions required a multi-year commitment, and few sources of revenue to the department were stable. This need was one of the primary motivations of the department's search for corporate sponsors and the development of institutions like the Honors Co-Op program and the Computer Forum. Their development provided significant sources of stable revenue, while also creating venues for industry scientists to engage and shape the direction of the department. Thus, the department's research was improved in two ways, financially and intellectually.

Thus, necessity was critical for creating an environment conducive to attracting

[75] Forsythe to W.F. Miller, 29 Oct. 1969, Miller Papers, SC208/2/13.

industry. The faculty's hesitation with the Honors Co-Op program in the mid-1960s is just one example of this phenomenon. A better funded department would most likely have focused more heavily on the development of doctoral candidates, if these debates are any indication. However, the department had little choice, and it is to its credit that the faculty not only adapted to this reality but also built programs that were well in-line with its goals. It is this this strong entrepreneurial culture and the desire to pursue all possible avenues to success that ultimately created a strong Computer Science department.

# Chapter 5

# Conclusion

Stanford's Computer Science department continued to grow in size and influence throughout the following decades. With the rise of the software and internet industries in the 1980s and 1990s in Silicon Valley, the department remains one of the most important stories in the history of computer science and research into university-industry partnerships. What were the major factors behind Stanford's success? Speaking just a few years after the founding of the department, William F. Miller wrote about the university's success in the field: "Being one of the early departments in getting our program announced, we got the cream of the crop for a few years and success continues to make more success."[1] Miller is certainly correct that speed was an important element in Stanford's success, but many other factors played an influential role in Stanford's ability to be competitive.

This study analyzed the development of the Computer Science department as an academic discipline within the milieu of Stanford's School of Humanities and Sciences. It first examined the politics of creating a new discipline within the academy, as well as how the consequences of these debates shaped the direction of the department. Next, this study explored the four factors that were primarily important to the rise and prominence of the Computer Science department, including a strong relationship with the Stanford Computation Center, an entrepreneurial culture among the faculty of the department, an organizational flexibility among the university administration, and finally, a need to engage with industry. The

[1]Miller to Manuel Rolenberg, 23 Oct. 1967, Sterling Papers, SC216/C1/14.

latter factor led to the creation of new networks with industry that were explored in the final part of this study, including the development of corporate relationships of mutual benefit and the development of new venues of engagement with industry, such as the development of the Honors Co-op program and the Computer Forum.

## 5.1 How an Academic Revolution Shaped a Region

These different components, while separated thematically in the study, are intimately related. One major pattern that flows throughout the development of the Computer Science department relates to the politics of knowledge, a concept that examines the social and political factors that shape the everyday construction of knowledge. This concept is particularly pertinent to the analysis on the development of computer science as a discipline. In the early years, the field was merely a part of the Mathematics department, one subfield of the larger area of numerical analysis from which Forsythe was hired. Computers may have been gaining importance in society, but a discipline had not yet developed with the mission of researching problems associated with their design and operation. However, this would soon change in universities across the country. At Stanford, Forsythe worked almost immediately to build up a program when he joined in 1957.

There were several factors that allowed the division to grow quickly in the early years. First, the leadership of Forsythe as both the head of the Computer Science division and the Computation Center provided a means of coordinating the two activities to positive effect. Unlike the debates at some other universities detailed in Akera,[2] computer scientists at Stanford only lightly engaged in the service/academic debate, believing that both elements were crucial for computer science to succeed. Thus, the faculty that would eventually coalesce into computer science was already relatively unified in their approach, which strengthened the discipline's case.

When the division began searching for faculty members outside of the traditional areas of mathematics, a disagreement erupted between the faculty members of mathematics who feared the encroaching of a new discipline and the computer scientists who desired to expand to new domains of human knowledge. In a way, the notion of Kuhn's scientific paradigms appears, as well as his analysis of the stages of a scientific revolution.[3] Mathematics as a discipline was opposed to the notion of computer science for a host of reasons, but ultimately, its opposition was part fear and part ignorance. The theories developed by computer scientists could radically alter the field of mathematics and its many centuries of history, and it simply takes time to adjust specialists to a new mode of thinking.

---

[2]Atsushi Akera, Calculating a Natural World, MIT Press, 2008.

[3]Kuhn, Thomas S. "The Structure of Scientific Revolutions." Third Edition. University of Chicago Press, 1996

The same issue is visible in the letter written by the chemist Paul Flory. He worried that a new discipline like computer science could be “lethal” to the university and that the “bulwark of the disciplines” that is H&S, would crumble with its addition. Flory was responding in a particular moment of postwar scientific culture. Vannevar Bush’s essay on science, with its separation of basic and applied science, represented the blueprint of that era. Computer science, though, does not cleanly fit into Bush’s system (which is surprising given his personally strong connection to the development of computing). Like other engineering disciplines, Computer Science benefits from connections to industry that are developed through programs like the Computer Forum. Yet simultaneously, the discipline is highly theoretical with important core results. It is this hybrid nature that makes the field so controversial, and yet, enriching to analyze.

How then did computer science navigate the political landscape of knowledge within Stanford? Two factors are important. First, the organizational flexibility regarding the appointments in artificial intelligence shows the forward-looking nature of the university administration. Part of the reason for this culture was certainly Frederick Terman, who is among the most powerful and influential administrators of Stanford in its entire history. However, Stanford benefitted from a system of governance that deemphasized the power of individual faculty members to the importance of building the university in directions of future promise.

Faculty members like Flory who were concerned about the development of applied science were essentially powerless to stop the trend.

Forsythe particularly benefitted from a university administration that was by education or by vocation already relatively connected to the issues of computing. Frederick Terman's mentor, Vannevar Bush, made major contributions to the development of computing that became very well-known among the general public. In addition, Terman's own experience as chair of the Electrical Engineering department likely assisted his decision in pushing for the development of a strong department in computer science.

Other administrators with direct budget authority over the Computer Science department had interests in fields that made them supportive of the department's expansion. Halsey Royden and Albert Bowker both conducted work in applied mathematics and statistics, a field with important connections to computing. Robert Sears, the dean of H&S, continued the work of Frederick Terman's father, and this close connection likely gave Terman influence over Sears.

Considering Forsythe's actions toward the university administration, including ignoring budgets and effectively merging the budgets of the Computation Center and the Computer Science division in the years before 1965, it is remarkable that the administration never once forced the department to halt its expansion. There is little question that the administration's enthusiasm for the department had a key role in its development.

Second, the Computer Science division quickly connected to other departments through interdisciplinary initiatives and research, building legitimacy with colleagues by spreading the value of its peculiar kind of research. One particularly useful component of this outreach was adding classes in other departments into the Computer Science curriculum. Few departments will say that their own classes are not a legitimate form of study, and few will criticize a particular collection of classes, especially when they have a defensible intellectual coherence.

In the end, Computer Science's spirited trajectory both assisted and harmed its development. The attention the growth of the field provided likely increased budgets earlier, thus reducing the time required to establish its place in the university. However, the field's underdevelopment certainly made the issue of academic legitimacy more palpable. The short span from its original conception to full department status is remarkable — only six years. It seems quite possible that a more mature field would have faced less controversy from other faculty members.

The political gauntlet faced by computer science did have repercussions. The Computer Science department at Stanford would not have an undergraduate degree for decades, largely because of the department's attention to graduate work. That focus is at least in part a response to the debates about the academic legitimacy of the field. Along these lines, initial faculty hesitation at programs to engage with industry may also have been affected by this debate. The Computer Science department would never truly fit in with the departments of H&S, but it would take almost another twenty years before the department transferred to the School of Engineering in 1985. For undergraduates interested in Computer Science, the department recommended a Mathematics major, and later an interdisciplinary applied mathematics major. Only by 1986 would Stanford authorize a bachelor's degree in Computer Science.

Thus, the combination of the politics of the academy and the need for more revenues created a strategic direction for the department that emphasized theory but also encouraged the practical application of results. The networks that were formed between Stanford, IBM, HP and the dozens of companies that joined the Computer Forum demonstrate the strength of this model. The Computer Science department is intimately related to the development of dozens of companies in Silicon Valley, and the creation of these linkages can be largely explained as a contingent development of the department's maturation in the 1960s.

The politics of knowledge then has had a large transformative role in how the department organized itself, what activities it engaged in, and how it approached its future development. Since Stanford was a leading department, and its model was a blueprint for other universities, the politics faced in H&S had large effects on the course of computer science throughout the country.

## 5.2 Areas for Further Research

As more sources become available, historians of science are now increasing their attention to the development of computer science as a discipline. However, there remains large holes in our current understanding. First, a better study of the political economy linking computers, computer science and defense funding would allow for a closer examination of the effects of science policy on the development of an academic field. This is particularly important given the significant effect of defense research policies on computation.

Second, further research must be made at the university level to understand the politics of knowledge that existed at different institutions. This study provides an archival-based history of the developments at Stanford, but this information must be put into a comparative framework to analyze the varying experiences of universities including MIT, Harvard, Stanford, Carnegie Mellon and the University of Michigan. Along this line, additional analysis is required of how these departments evolved, and why universities specialized in particular areas.

Third, the connections between mathematical research and computer science needs to be further explained. The biographies of many of the pioneering computer scientists include a mathematical preparation, and this background provides a particular perspective on the development of the field. However, the development of a notion of computer science changed this biography in later generations. What are some of the problems associated at the interface between these two groups, and were there different approaches to evolving the field?

Finally, many of these components can be seen in the publication of the model curriculum developed by the ACM. Forsythe himself was highly involved in such efforts and was a passionate advocate for education in computer science. However, there has not been significant research to see how universities adapted the model curriculum to their own institutions. Such research would connect with the politics of knowledge framework, and could provide a strong comparative model from which to analyze.

The history of computer science provides a remarkably untapped area of research that can and should be explored. Our growing understanding of the ways in which social and political factors influence the course of research has the potential to illuminate the important origins of computer science, a field that will shape the world for years to come.

In terms of regional studies, there is significantly more work to be done on understanding the development of regional innovation hubs. First, there is an important new strain of research in spatial history that needs to be further explored. The co-location of industry and universities has become a commonplace in the development plans of most regions, but the exact nature of the relationship between them remains unclear. Particularly with the advent of online communication tools, the research on geographic proximity has the potential to be of immense value.

Second, along similar lines, there needs to be a more encompassing study of the ways in which public policy can influence the development of innovative economies. The research on military funding in the 1950s has become the default answer for scholars to answer how Silicon Valley began. However, the region was comparatively small compared to its Boston counterpart, and received fewer government grants as a result. Therefore, the connection between government funding and innovation is significantly more complex.

Third, and one of the main areas where this study has attempted to shed light, is how the development of new disciplines on the edge of existing academic fields can be used to coalesce a new industry in a particular region. The development of entire new fields happens continuously as our understanding of new domains of knowledge increases. Regional planning authorities should take advantage of these new disciplines as spearheads to build new industries with limited competition. However, to do so requires an understanding of their formation, and this is the role that research can fill.

In addition to these research strains, there is also a need for a more expansive look outside of the United States across all of the literatures connected to this study. Significant comparative research remains to be conducted on the approach of foreign universities to new disciplines, and how the politics of knowledge are influenced by local academic culture. In addition, the pursuit of regional innovative hubs has been conducted mostly outside of the United States, and has been largely a disappointment for the governments that have sponsored them. The connections between industry and academia, and the underlying ecology between them, needs to be closely studied.

Regional studies as a whole has a remarkable future. As cities work together to solve joint problems like traffic, land use, housing and economic development, researchers will have significantly more effect on the direction of public policy. Some of the most complex policy problems are regional in scope, and further research into any element of them will create a stronger, more vibrant economic picture of the United States – and the world.